PROCEEDINGS OF THE P E R T COORDINATION TASK GROUP MEETING

17-18 MARCH 1960
16-17 AUGUST 1960

NOVEMBER 1960

SPECIAL PROJECTS OFFICE
BUREAU OF NAVAL WEAPONS
DEPARTMENT OF THE NAVY

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SPERRY GYROSCOPE CO.
GREAT NECK, LONG ISLAND

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1. Enclosure (1) provides a summary of the proceedings during the subject meeting.

K M Tebo
K. M. TEBO
By direction

INTRODUCTION

This meeting of the PERT Coordination Task Group was opened on Thursday, 17 March 1960, by Captain Kenneth M. Tebo, USN, Head of the Program Evaluation Branch, Special Projects Office.

A welcome was also extended to the Task Group by Mr. W. R. Griswold, Manager of Sperry's Marine Division, and by Captain O. N. Fowler, Special Projects Office Technical Representative, resident in Sperry Marine Division at Syosset, Long Island.

The meeting was directed primarily toward a review of the PERT system in operation—at FBM contractors and at non-POLARIS activities. In addition, a proposed plan for decentralized PERT computer operation was presented and discussed.

ROSTER OF PERT COORDINATING TASK GROUP MEETING
17-18 March 1960

Aerojet General	J. E. Molder
Control Data Corp.	H. R. Lindquist, R. S. Erickson
Curtiss Wright	Mr. R. F. Jones, W. Imbrie
Dunlap & Associates	C. Von Wrangell
Edo Corp.	J. A. Mathews, A. Bjorski
Electric Boat	H. D. Motin
General Electric	H. G. Francis, K. Brown, J. Perlman, G. D. Robertson
Interstate Electronics	D. L. Ewing
Lockheed	J. F. Mullen, Jr., J. D. Blitch, F. F. Robbins
MIT	K. Dunnipace
Minneapolis-Honeywell	J. V. Wilson
Raytheon	T. D. Cutler, R. E. Fioncello
Reflectone	N. R. Franc, Jr.
Sperry	W. Griswold, R. Greaves, K. Williams, S. Fedotta, M. Siskind, D. Goff, J. Quida, M. Crean, M. O'Brien, C. Kirsten, B. Moore, C. Mirrione
Sylvania	C. Fink
Westinghouse	D. Burnham
BuShips	Cdr. R. R. Kemp, USN, C. Reuter
Naval Weapons Lab.	R. Learn
NASA	W. W. Haase
NTDC	G. Horsenuth
RINSMAT, Calif.	R. N. Williams
INSMAT	J. Cincotta, W. C. Logan, C. W. Spencer
Spotr	Capt. Fowler, USN, S. A. Cariski, G. Guler
SupShips, Groton	Lcdr. T. M. Hopkins, USN
SupINSMAT	Capt. W. McTang, USN, Cdr. F. F. Adams, USN, R. Hacks
Special Projects	Capt. K. M. Tebo, USN, LCdr. Sullivan, USN, Lt. S. Kingsley, USN, Ltjg. D. Geri, USN, Ens. M. I. Farfel, USN, Y. Nakayama, H. W. Callaway, J. Bazuin, Ltjg R. Mogle, USN

PERT COORDINATION TASK GROUP MEETING
Remarks of Capt. K. Tebo, USN
Sperry, Great Neck, N. Y.
17-18 March

Many of you who are here to participate in this second meeting of the PERT Coordination Task Group were not with us at the first meeting last September. The agenda you have, and earlier documents addressed to your organizations, give an indication of the purpose for our assembly today, tomorrow and again in the future. Let me say, in brief, that we are here to increase the effectiveness and usefulness of PERT for all participating members of the FBM customer contractor team. Intelligent communication and exchange of information on progress, developments, problems and experience related to PERT should yield reciprocal benefits and greater profit from the application and use of PERT for all parties—leading toward the end-objective of improving our individual and combined capacities to meet FBM program deadlines.

Since our first meeting, many advancements have been made in the application, operation, and use of the PERT technique.

Application has been extended to many additional contractors developing or producing weapon system equipments and non-weapon system submarine equipments.

Aerojet adopted the system for processing Propulsion PERT data on its own 704 computer and for internal management and technical administration.

Lockheed (LMSD) in turn is processing PERT for the Missile Subsystem and Components on its 709 computer, with a procedure for direct communication between the LMSD 709 and NORC computer. Punched cards on PERT inputs are being furnished by Lockheed's 709 staff in Sunnyvale, California direct to the NORC computer in Dahlgren, Virginia. Yuki Nakayama and Bob Learn are on the agenda to tell you about this.

LMSD transmits to Sp, its own analytical statements on problems revealed by PERT, containing the specific preventive actions taken or contemplated within LMSD and actions recommended for execution by Sp.

MIT has taken the initiative in PERTing the effort required to develop the second generation POLARIS guidance system—by developing a network containing more than 700 events or benchmarks.

Better communication and coordination has been afforded by PERT among a variety of contractors whose inter-dependent efforts are required to meet certain specific FBM objectives, e.g., completion of the FBM Team Trainer which requires the combined effort of EB, Curtiss-Wright Reflectone, and Minneapolis-Honeywell.

Adoption and use of PERT outside the FBM program gives indication of rapid acceleration in near future application by many more contractors and Government agencies. For example:

Jerry Pearlman is on the agenda to tell you about the application experience of GE's Light Military Electronics Division.

Bendix on its own initiative is undertaking application to the Navy's EAGLE program.

Air Force is beginning application to several missile and aeronautical programs—and being "needled by General Schriever" to go PERT.

SP is taking steps to make important additional advancements in the near future. A PERT orientation tool. Copies should become available in May or June—and some of you may find this film useful for stimulating the interest of top management of other divisions of your own companies and of top staff not directly involved in PERT operations.

We have a small study contract with a research firm for the examination of PERT operations for the purpose of recommending to SP, ways to improve PERT's usefulness. A representative from this firm, Dunlap and Associates, is with us today—Mr. Charles Von Wrangell. Their study will include recommendations for minimizing reporting bias, for reducing time between the provision of PERT inputs and the taking of executive remedial or preventive actions, and for having PERT take advantage of "learning" from past history or experience.

We are sponsoring another applied research task to develop a system for PERT estimating of costs and cost outlook—with an objective for developing a comprehensive system for making better distribution of costs or resources to accomplish end-objectives.

IMPLEMENTATION OF PERT FOR POLARIS MISSILE
Brief of Remarks by Mr. J. Blitch and Mr. F. Robbins, LMSD

After introducing Mr. Mullens, Project Control Manager and Mr. Robbins of LMSD, Mr. Blitch reviewed PERT experience at LMSD, including current status, organization, information flow, and the coordination and verification process. A brief of his presentation follows:

In October 1958, LMSD began sending inputs into SP for NORC processing based on individual subsystems of the POLARIS missile. The networks and inputs were somewhat unsatisfactory until November 1959 for several reasons. Insufficient exchange of ideas, plus the distance between SP and LMSD, inhibited speedy clarification and mutual understanding of problems involved in implementing PERT. The selection of events, a fundamental requirement, left something to be desired. Mr. Blitch emphasized that events must be completely unambiguous in meaning, readily identifiable as points in time, and distinguishable from activities which reflect work in process. Another difficulty encountered during 1958-1959 PERT operations was the delay in availability of PERT outputs for LMSD personnel who provided the inputs—usually two weeks or more in the mails or at NORC.

Recognizing the need for improvement in PERT system operations at LMSD, the PERT group developed an end item, long range network covering

the entire effort involved in getting out the first tactical A1 missile. This provided the first real practical use of PERT. Steps to the end-item were outlined and time estimates obtained. Contrary to PERT procedure, time was shown on the base of the chart and the steps were evolved working from left to right toward the end objective. By fall of 1959 as production neared, a different approach was needed, since previous efforts and general purpose of PERT at LMSD were devoted exclusively to R&D. Using a tactical missile as the end item and working backward through the steps involved, an effective chart was constructed. Following presentation to and acceptance by SP in late November 1959, SP issued a directive in early December calling for a complete PERT report on the A1P missile by 15 January and use of the LMSD 709 computer.

A PERT Task Group, consisting of 3 people, was organized at LMSD and its mission was to ensure proper implementation and use of PERT as a tool at all levels of management within the POLARIS Missile Systems Division. In addition, the task involved indoctrinating those who were going to participate, obtaining the inputs, and programming for the 709 computer. LMSD borrowed Aerojet's 704 computer program and, after considerable adaptation and experimentation, usable print-outs were obtained and the SP deadline met.

Experience with this "Crash" program pointed up a particular need for educating and understanding of the system by all concerned ranging from top management to those who fill out the PERT forms. The education process must cover, in addition to network content and completion of forms, use of computer outputs in analysis of program status and integration of analytical results back into PERT program for use of those making the inputs.

Mr. Blitch reviewed the PERT work flow plan (Exhibit 1) and then discussed the networks depicting LMSD responsibilities for the missile, surface support equipment, and integration of the missile system into the overall FBM system. The missile network (designated 1,000) consists of rather broad and general events—activities leading up to the manufacture of the first missile and a line going over to show shipment of the last missile of the lot, about 20 missiles in all. Back-up charts for this network pertain to the component subsystems—ballistic shell, internal system, flight controls, reentry body, and exercise head, and inputs from GE on guidance and from Aerojet on propulsion. The supply support equipment network consists of check-out equipment, containers and ground handling equipment. The integrated network covers all LMSD responsibilities for integrating the missile into the over-all FBM system. At LMSD each event times on the critical paths are analyzed (i.e. any path with zero or negative slack on all back-up charts) and the combined normally for analysis of the networks.

Probably the toughest job is plowing PERT outputs back into the program for use locally as a management tool. Print-outs require intrepretation. The analysis cover all areas whereas the managers are interested generally in their specific areas of effort only. PERT is new and there is a general antipathy for change. In addition PERT is superimposed on busy people as an added chore until its value has been demonstrated and can replace other methods of planning and reporting.

Steps for improvement in process at LMSD include: development of a new program for 709 computer; construction of network and charts that can be reduced to usable desk size; selective internal distribution of print-outs and analyses to those interested; use of PERT results in bar chart form for top management; and a continuing expansion of PERT orientation program. While carrying out the above steps, plans have been to extend PERT into other areas.

Mr. Robbins then presented the new program for the 709 computer.

PERT CONFERENCE AT SPERRY GYROSCOPE

Remarks by Mr. J. Pearlman, GE-LMED

(N.B. Only selected vu-graphs have been included.)

I do not believe that I must explain in any depth the network which you see before you as my first slide. Rather than discuss any of the basics of PERT, even at General Electric—Light Military, I should like to probe into what I consider to be our approaches to or extensions of the PERT planning tool.

I would like to discuss with you today six areas of work. The first two would be the history of work at LMED and how we have implemented PERT. Then in discussing our extensions, we will cover four broad areas; namely, manpower, facilities, choice of alternatives, and total planning by the use of PERT. I should like to emphasize at this time that the PERT Program Planning Tool, although initially implemented in Engineering, has definitely and most emphatically spread to our Manufacturing and Quality Control organizations also.

We became aware of PERT a little over one year ago and were able to secure an appointment with Captain Tebo, who gave us a very fine presentation. We were convinced at the time of this presentation that PERT had application at Light Military in the Engineering function, and returned to Utica to study how we might experiment with its implementation. After a little contemplation, we selected as our trial guinea pig a large airborne radar which was being designed and developed at two Light Military locations, 95 miles apart, involving two major subcontractors, each one requiring a very major breakthrough in the state-of-the-art. We chose this program for several reasons. First, the program was in some trouble. Secondly, the program was sufficiently large that it would show the ability of PERT to operate as a total device, but at the same time, was not so large that the implementation would take too long and the results of our experimentation would not be timely. Thirdly, the pro-

gram was already sub-divided on a black box basis to aid in our experimentation.

As you can see, this next slide is a graphic portrayal of how we operate with PERT from this initial experimentation. We have a three pronged cycle that is a true closed loop. First we plan, then we replan, then we measure our performance and predict, and go back to planning and replanning. For purposes of illustration, we have a very simple PERT network which will show broadly what we do.

The first point I would like to make is to call your attention to the fact that we sell from the bottom, that is to the Engineers who are working on the program. We explain to them the PERT technique, its potential advantages, and how they themselves could use it. PERT caught on very rapidly this way for it permitted the Engineer to put on paper his own thought process and apply something which is near and dear to his heart; the use of probability. Furthermore, it appealed to him because at last he was allowed to program his pessimism and his optimism, and, therefore, probably come up with a more reasonable estimate of how long individual tasks might take in terms of time. After we sold the individual Engineers, we sold the Project Engineers, the Unit Managers, the Managers of whole product areas, until, finally, we explained what we were doing to the Manager of Engineering. Let me say at this time, it was quite a number of months before the Manager of Engineering knew the details of our PERT implementation. He knew that we were selling PERT, but he was not exactly certain what PERT was. Furthermore, let us look at the word "sell." Program planning and measurement is charged as a contract expense to the particular job so that when an engineering group bought our services they had to forego an aspect of their program originally estimated.

Our technique of implementation operates thus: A representative program planning engineer from my group will sit down in the first planning meeting with representatives from Engineering and Manufacturing and Quality Control. If a proposal is being prepared, then a representative from Marketing will also be involved.

A network is evolved first and then the three times are applied to it. This is then subjected to a computer analysis, and, as usually happens, the critical path from beginning to end will come out with too long a time. A replanning is then done in which the effort is re-evaluated. I would like to stress a very important ground rule which we have established. Our experience indicates that the time estimates first made are best so that we do not change time estimates, except under two conditions. First, the rate of effort or particularly the rate of application of manpower is altered in an event where more manpower can aid; or, two, the actual objective of the event is altered. For instance, a final schematic might have originally been required, but now a sketch of only three or four critical circuits would be required. After this, the program is naturally followed and measurements of completion are acquired; also, changes to the network are acquired and put through the computer analysis to determine what will happen. Our cycle then shows another planning, replanning and prediction phase if the changes or the completion dates have affected the actual probability of success of the program.

The integration among Engineering, Manufacturing, and Quality Control bears some explanation. Our experience indicates that a good share of the PERT benefit is achieved just through an exchange of ideas and problems. Fifty percent of the time required to develop the program plan is used in making decisions—decisions which might have caused a panic if they were required in the future.

This next slide indicates the areas in which we have successfully applied PERT. I don't believe that I need to go into detail about how we have done it in research and development. Most of you gentlemen are familiar with this aspect of the application of PERT, probably more than any other aspect.

There is involved in most programs a production planning phase. As you well know, there are cycles for the preparation, design and manufacture of tooling. In electronics, we have this cycle on test equipment. In addition, there is a lot of planning which must go on into our production phase for determination of the manufacturing line layout; the training of personnel, the construction of jigs and fixtures, and the preparation of small expendable type tooling. Also the ordering of material and the receiving cycle is a prime problem. This production planning cycle, because it is non-repetitive, is exceedingly amenable to the use of the PERT technique.

We also have the problem of production cycling. How long does it normally take to produce one unit if we have a one shift, 40 hour operation, and if all of the individual sub-assemblies are manufactured by one person only. In many cases, this type of analysis is exceedingly revealing, particularly since the critical path will actually point out where a potential bottleneck or queue in production capacity might exist. This leads us to the next one, or capacity analysis, for as we can use or apply time to a PERT network, we can also apply the number of units per fixed period and hence develop a capacity analysis to determine whether we are over capacity or under capacity in particular positions of fabrication, assembly, test, or inspection, and in this way ascertain what might happen to us under various production loadings.

Our present computer output looks as you see before you. We show the earliest expected time, (working forward in the network), the latest expected time, (working backward in the network), and the amount of slack. Also, we pull out and sort the critical path elements. If scheduled milestones exist, we show these also and the probability of successfully meeting the end event and the intermediate milestones is also shown. This type of presentation is fairly straightforward, and I am sure all of you are very familiar with it.

I should now like to cover some of the extensions of PERT. Just to refresh your memory, we will

cover manpower and labor cost analysis, facility analysis, alternative selection and the use of PERT as a total planning tool. If, as illustrated on this PERT network, the lines between the events represent the elapsed time, they also represent the use of resources. Time can be called one of our resources just as manpower and machines and space can also be called resources. Therefore, if we apply to our time estimates an estimate of manpower requirements, we can derive an analysis of our personnel utilization. Essentially, we code people by their skill and by their talent. For want of better terms, we define skill as their basic background; Engineer, Technician, Draftsman, Assembler, Tester, etc., and talent might be even more specific, such as Electrical Engineer, Electrical Engineer-Servo Mechanism, etc. Since the problem is merely one of computer capacity and symbolization, the number of subdivisions can become fairly large, although probably uneconomical.

This computer output shows how we analyze our manpower. You can see on this first chart that we have shown our skill codes and our time estimates. Time is on the ordinate; skill is on the abscissa. The matrix is then filled with the number of events which each skill code is doing in the particular portion of time, be it a week or a month. The most important part of this output are the holes, the spaces, where a particular individual or group has nothing to do. I am sure you can see that as you look across a large program and if each designation on the abscissa were an individual, then it should be possible to reshuffle the number of people by making those individuals who have nothing to do in a particular period, do the work which other individuals are doing in that period. Hence, it must be possible to reduce the number of people involved in a program. The next report shows the totals by various skill and talent levels. These can then be used for the next report down, which gives us our dollar values.

The mere addition of an average rate is relatively simple and by the multiplication of people times rate, we come out with labor dollars. However, this is not entirely what we wish to do. We have found that we must assign penalty rates for low utilization of personnel. That is why you see a column titled "Percent Utilization." Therefore, if an individual organization or skill category is being utilized to 90% capacity, and we are paying for it to the tune of 100% capacity, we have a serious problem in terms of cost. In this manner, we can measure the relative cost/schedule efficiency of our program.

If we wish to be very callous, and for the purpose of an inanimate type of presentation such as we have here, we shall be callous, we can consider that a man and a facility such as a vibration machine, are one and the same. To the computer, they are identical. The only difference is their symbol, and the computer has no feelings of emotion whatsoever. Therefore, as you can see, the manpower analysis in front of you, by merely changing the symbolization, is also a facility analysis. It would be very simple to take the letter "A", and rather than say that "A" is John Jones, we can say that "A" is a random noise shaketable. Therefore, I am sure you realize that when one has programmed the manpower aspect, it becomes relatively straightforward to handle the facility aspect.

When planning and replanning, another aspect which became very important to us, is our ability to select alternatives or select one or more among many alternatives. This becomes important, for instance, in our design operation if we wish to consider whether we should transistorize or use standard tube circuits; whether we should go for a complete break-through in the state-of-the-art; whether we should do a lot of preliminary Engineering; or any other element along these multiple alternative lines. We have found that to make an analysis of which of many of alternatives to select, we have had to consider several areas. First, it was necessary to assign priorities or weights to our events. That is to say, those priorities or weights were used to designate that either the event was mandatory and could not be altered in objective or any way, or that it was definitely a successor or predecessor event to a particular set of events. In this way, the machine could put in the constraints so that it would not randomize entirely along the network. Secondly, we program the machine to shift events after considering these constraints. The machine actually tries all conceivable alternative or iterations in a very short time. A human cannot do this very conveniently. The third technique which we use is to program all known possibilities in the very beginning. True, we do not have all possibilities, but we do have all the major ones. In this way, the critical path immediately tells us which of the possibilities might be the trouble-maker. By coming out with several ordered critical paths, we can quickly make choices among alternatives. However, the technique which we have found to be best is event shifting, whereby we can actually optimize or tend to optimize our schedule to ascertain the minimum schedule.

Since we can select our alternatives for schedule, we also can select our alternatives for manpower. Since we can do each one independently, we can optimize between schedule and cost. Therefore, we have successfully used a method of minimum manpower/time schedules. It is necessary to choose among our constraints and set boundaries on the minimum and maximum schedule and then allow our manpower to vary as required to achieve the best situation. There are times when in order to achieve a major reduction in cost, it can become necessary to alter our schedule. However, these kinds of decisions are easily made on a value judgement basis, and therefore, we can choose among many combinations of these alternatives.

Since we can do these operations on a project basis, we obviously can use them as a total planning tool. We can sum the manpower being used on individual projects to achieve total manpower utili-

zation for the complete and entire Engineering function. We can do this on a talent and skill level relatively easily. We can also pick our specific shortage of skills, such as we'll say Servo-Mechanism personnel, and program their application to projects over a given period of time. Since we can do this for Servo-Mechanism individuals, we can do it for a random noise vibration machine, and hence, we can measure our facility loading at all times. This has allowed us to predict the loading to the point that we can smooth the peaks and valleys which are typical on this kind of machinery. We have, as an example, a punch card facility for preparing much of our drawing release, and we have found from experience that there is a considerable peaking in this facility. We can, with PERT, and have, in fact, been able to smooth the application into this area. Since we can determine the utilization of our resources, we can simulate the business operation of the Engineering Section. It is relatively simple for us to superimpose on top of the summation of manpower and the facility loading, the constraints of turnover rate, ability to hire personnel, lead time to obtain various facilities. By so doing, we can very easily measure the effect of new programs and projects upon the Engineering function. I cannot stress this total planning concept enough. I also must stress that PERT is a very basic planning logic. Since it is logic, it lends itself to simulation.

For the purpose of presentation of our material to management, you see before you a type of bar chart presentation which we have used. The major milestones off the critical path are placed in the triangles. The chart along the right portrays for each of the major areas and programs, the number of days or weeks, or months, behind or ahead of schedule. This is very easily determined from the critical path. Along the bottom you see the trend of the probability of successfully meeting the end objective. We have found that this trend does not fluctuate violently, but rather is relatively smooth. Therefore, it is of extreme importance in management control.

This next slide shows a completed network. This kind of information is used by our individual personnel, either in Engineering or in Manufacturing. I might stress that I have personally seen little networks for a week's work or the time between two events which appear in the network you see before you, used by our individual personnel; the individual Engineer, Industrial Engineer, or Production Planner. This kind of information is readily maintained. None of these forms is very fancy. They are all prepared on vellum paper in pencil and ozalid reproductions are made. We found from our experience that to go into fancy reporting will negate the use of PERT as a planning tool, and an insurmountable amount of paperwork will reduce PERT to a Plague instead of a Boon.

One more point, if I may? We almost never put a PERT application on the computer before we have shown feasibility manually. It is not our intent to *load* our scientific computer. With the cry of "more information for management" we can easily be trapped into reports for their own sake. Manual proof has avoided this problem.

This has been a brief summary of the work that we have done at The Light Military Electronics Department of the General Electric Company in Utica, New York. We shall be pleased to answer any of your questions at this time.

HOW THE CURTISS-WRIGHT COMPUTERIZED MANAGEMENT SYSTEM OPERATES

Extract of presentation by Mr. W. Imbrie, Curtiss-Wright

I. PLANNING PHASE

A. Scheduling–

1. The program manager establishes a basic list of required tasks including the following information:

a. Job description and temporary identification number.

b. Job cycle time.

c. Job sequence.

d. Responsibility and man-type or types assigned to each job.

e. Man-days effort required for each man-type.

f. Procurement costs for each job.

This information is recorded on the *Programs Planning Work Sheet* (see attached Form F1) and turned over to the Programs Planning and Control Group.

2. The Programs Planning and Control Group assigns a ten digit job number to each job on Form F1 and transfers the data to computer input sheets (see attached Form F2). The information on the input sheets are punched on cards which make up the basic R & D program input deck.

3. The input deck is fed into the computer and a planning schedule is calculated. This schedule output is sorted with other information and listed as the Master Schedule (see attached Schedule F-3).

4. Copies of the Planning Schedule are turned over to the Programs Manager for negotiation and revision. The schedule is negotiated with those persons assigned to the various jobs and with Management until an agreement is reached. The schedule is then frozen.

5. This frozen schedule (Original Schedule) is distributed to all persons responsible for carrying out the assigned tasks. It is their responsibility to report against this schedule until revisions are issued.

B. Costing–

1. Using the input deck and the original schedule output cards a cost input deck is prepared by Pro-

grams Planning and Control.

2. The cost input deck is fed into the computer and program costs are calculated. (See attached Cost Data F4.)

II. OPERATIONAL PHASE

A. Persons or organizations with assigned responsibilities report weekly against the latest Master Schedule in their possession. The following information must be reported by a given deadline—

1. All jobs completed and the dates of completion.
2. All jobs cancelled and the dates of cancellation.
3. All reschedules of old jobs including revisions to start and end dates, cycle time, job sequence and assigned responsibility.
4. All additions of new jobs including start and end dates, cycle time, job sequence and assigned responsibility.
5. The fact that no changes are required must be reported.

(See attached Report Form F5.)

B. Program Planning and Control receive Weekly Engineering Reports (F5) and transfer this information to the program data processing cards. Old job cards are pulled, revised and replaced in the deck. New job cards are made up and added to the deck. The revised input deck is fed into the computer and two schedules are calculated—

1. "OPEN" schedule which is the schedule based on the latest job cycle times and sequence promised by those persons reporting. (See attached Schedule F6.)
2. "CLOSED" schedule which is the required schedule based on the original program target date. (See attached Schedule F7.)

Those two schedules are printed for analysis and distribution.

C. The revised "OPEN" and "CLOSED" schedules are reviewed by Programs Planning and Control and by the Program Manager as follows—

1. The "CLOSED" schedule automatic overall program status indicator is checked and plotted on the monitoring report—program summary. (See attached Form F8.) This immediately shows if the program is in trouble and what the trend is. If slippage is indicated a more detailed investigation is required to determine the cause and to initiate appropriate action.
2. Current trouble spots are located by checking the automatic current late job indicators and critical job indicators.
3. Potential trouble spots are located by checking the potential late job indicators. This indicator lists those jobs which will be held up due to current late jobs.
4. Other potential trouble spots are located by locating future critical jobs and making comparisons between the original promised schedule, the current promised schedule and the computed required schedule.
5. The person responsible for, and the cause of slippage is established. The Program Manager then takes appropriate action to remedy trouble spots and to short-cycle specific future jobs to make up for the current slippage.

D. The new "CLOSED" Master Schedule is distributed to all responsible persons and organizations. The next weekly reports are made against this revised required schedule.

E. Weekly or bi-weekly program review meetings are held and are attended by Responsible Representatives from each Area, the Program Manager and Programs Planning and Control. The purpose of the meeting is to review the latest Master Schedule with the Program Manager. The following items are reviewed—

1. Overall program status.
2. Current trouble spots.
3. Potential trouble spots.
4. Schedule inconsistencies.

Action is taken to alleviate trouble spots and to short-cycle specific jobs to improve the schedule.

EXPERIENCE IN OPERATING A DETAILED PERT SYSTEM IN A FLEXIBLE PROGRAM

Remarks by Mr. J. E. Molder, Aerojet General

PERT, as applied to the Aerojet-General Corporation's portion of the POLARIS effort, is nearing the end of the first year of operation. Hence, a reflection upon the events and activities of this critical period seems most apropos.

The early months of 1959 marked the introduction of the PERT complex to the project personnel. During this period, the Project's programs, as in all research and development efforts, were fluid and fast moving. Design details, events, milestones, activities, and their interdependencies were difficult to define and organize. Hence, considerable credit may be given justifiably to those people who administered the indoctrinational proceedings in that they were able to establish the technique within the planning operations of the programs themselves. One of the key tools developed and utilized during this period was a brochure entitled "An Introduction to PERT."

Frequent and continuous discussions such as these did much to point up the value of the technique and win the support of the technical people—a group normally reserved in their endorsement of "paper-planning" devices. While it was quite evident to all concerned that PERT was valuable as a status reporting device and as a spotlight to focus attention upon problem areas, some difficulty was experienced in using PERT to lead performance, as

in business games. However, several simulation studies have demonstrated the potential of this analysis process, and today PERT is on the threshold of enjoying complete acceptance in the areas of planning and programming.

Typical of these early simulation studies is the work on introduction of light-weight second-stage motors into the A-1 program.

The initial organization for PERT reporting utilized adaptations of the Booz Allen Hamilton forms and the functional personnel structure of the projects. Mr. Molder discussed working sheet and data-gathering reporting documents and the approval process within the organization.

Today, the PERT reporting function has evolved into a more comprehensive technique. While the basic flow pattern persists, the reporting documents have been completely altered as illustrated by revised Flow Chart and Reporting documents.

PERT OPERATION AT MIT

Brief of Remarks by Mr. Dunnipace, MIT

Mr. Dunnipace covered three general areas: organization and purposes served, problems encountered, and techniques peculiar to the MIT PERT operation. Progress in PERT was indicated below the desired level—at MIT, about 6 months behind, and the GE and Raytheon work, about one month behind. The kind of problem involved is that the current major objective on which the PERT outlook is based is 70 weeks away but according to the current plan will be about 50 weeks late. Actions to avoid such a result were discussed later.

For guidance, there are three basic programs or networks. MIT maintains and operates one which covers MIT's over-all responsibility for the advanced guidance system, and it has inputs from both GE and Raytheon in their industrial support functions. GE and Raytheon are also building up their own networks which, although closely related, will operate independently.

PERT serves a variety of purposes: shows when design freeze is needed by area, and the effects of later changes, provides a better opportunity for keeping track of all the inter-related tasks than anything MIT has tried before, and specifying the jobs that have to be done by the prime or subcontractors.

The major problem in PERT operation is getting a complete network. Many schedules are being generated, and it is a real advantage if you can participate at the right time and preserve the sequence relationships developed during the process. It is easy then to transform this information into a PERT network and get your inputs for the computer. It is of real benefit when the PERT system is accepted by the group leaders. Time estimates can be developed with reasonable reliability. A basic need is appropriate presentation media for the group leaders. Among others, bar charts can readily present status but not analysis, and color coding charts can be used but they are rather complex.

Mr. Dunnipace also presented the numbering techniques used by MIT to rapidly identify their networks and events, including those used at GE and Raytheon; the PERT formats, critical path analysis, and progress reports.

DECENTRALIZED PERT OPERATIONS WITH CENTRALIZED MANAGEMENT CONTROL

Remarks by Y. Nakayama SP 121

When SP started the PERT operations over a year ago for the FBM Weapons System Program, computer processing was done only at NORC, Dahlgren, Virginia. All contractor PERT computer reports were handled through the Special Projects Office. SP served as the liaison with the NORC computer providing a central clearing house for feedback of computer outputs and SP PERT analysis thereon to the contractors. The procedure employed is diagramatically shown in Exhibit 1. One of the major shortcomings of this procedure was the considerable time lag from the point of contractor submission of reports to contractor receipt of PERT computer outputs and analysis. In most cases, the PERT computer results no longer reflected current contractor operations.

In order to reduce the gap in the time lag and to make PERT a more effective management tool, we have instituted at LMSD a new procedure in January of this year. Instead of using NORC, LMSD has programmed PERT on their own computer and is processing their own PERT inputs. Based on the computer runs, LMSD is providing SP with PERT computer outputs, analyses, actions being taken in problem areas as well as actions required of SP. The procedure established for LMSD also provides for transmittal of computer cards directly to NORC, to be used by SP for FBM Weapons System integrated PERT computer runs and for simulation runs to improve SP planning. This procedure is diagramatically shown in Exhibit 2.

What we are proposing today is the extension of the PERT procedure established at LMSD across the board for the FBM Weapons System program by regionally decentralizing the PERT Computer operations. We believe that the PERT coverage of the FBM Weapons System contractors have reached a point which justifies this extension. The plan envisions dividing the country into three regions for computer operations purpose. Region 1 covers the Pacific Coast and the Western states, Region 2 covers Midwest and South, and Region 3 is for Northeast U. S. contractors. Computer Centers will be located as follows: Region 1—LMSD, Sunnyvale, California. Region 2—NORC, Dahlgren, Virginia. Region 3—Sperry, Great Neck, Long Island.

The proposed procedure would work as follows:

1. Contractors would send their PERT computer inputs to the assigned regional computer center.

2. The regional computer center will process the input data and provide the Special Projects Office and the contractors with computer outputs on a simultaneous basis.

3. Contractors will use their computer outputs as a basis for submitting to Special Projects Office

PERT analysis of contractors' outlook, problem areas and actions being taken by the contractors as well as actions required of SP.

4. The Regional Computer Center will send the current computer cards directly to Dahlgren for SP use in FBM Weapons System integrated PERT computer runs.

The proposed decentralization plan is shown in Exhibit 3.

It is anticipated that the plan for decentralized computer operations will not only accelerate the feedback of PERT outputs to the contractors, but will provide the contractors with the opportunity for timely participation in the SP's over all program evaluation responsibility. Most important, the plan will facilitate greater concentration of SP efforts on its prime mission for over all FBM Weapons System Program evaluation.

COMMUNICATION AND COORDINATION BETWEEN COMPUTERS IN DECENTRALIZED OPERATIONS

Remarks by R. Learn, NAVWEPLAB, Dahlgren

If the decentralized system as described by Mr. Nakayama is implemented, the major workload at Dahlgren in connection with PERT will be in the areas of simulation and integrated runs. First I would like to make a few remarks about the integrated runs. The integrated runs are those in which the events of two or more subsystems are merged together creating a large system which is then processed by the NORC. The resulting PERT report gives a more comprehensive evaluation of the FBM System than would be obtained from the reports generated by processing the subsystems separately. The *key* to merging the subsystems together is the *event code*. In PERT, events are identified by a nine digit event code. The first six digits are used by SP to identify the cognizant SP branch and the subsystem; the last three digits are used to uniquely number each event in the subsystem. Therefore, each event in the entire FBM System should have a unique event code. There are, however, events that are common to more than one subsystem and these common events should have the same nine digit event code. For example, there may be in both subsystem A and subsystem B an event titled "Test Flight (X) Completed." Then the event code for "Test Flight (X) Completed" in subsystem A would be identical to that used to identify event "Test Flight (X) Completed" in subsystem B. A special event code has been set up so that these events, common to more than one subsystem, are easily distinguished from the other events. The first six digits of the special event code are "010 000." The last three digits will range from 001 to 999 and will be assigned by the contractors as directed by SP 12. In our above example, "Test Flight (X) Completed" would be identified by the code "010 000 001" in both subsystems A and B if SP 12 specified "001" as the last three digits of the special event code. This special event code enables the NORC to automatically recognize the interrelationship of events in the subsystems that are to be integrated and process them accordingly.

Another aspect of the decentralized system is the standardization of communications between the computing centers. At present the contractors use the standard PERT transaction document when submitting PERT date to SP 12. This form specifies what data is necessary and the form in which it should be. This transaction document would not be necessary in the communications between the computing centers; punched cards or paper tape could be used. However, the same data and the same form of the data would be preserved. Effectively, we would just change the medium for reporting. The punched card or paper tape data, being in a mechanized state, could be readily transmitted via TWX and thereby speed up the reporting cycle.

For the PERT system to be effective and efficient we need both the standardized event codes and standardized communications.

DECENTRALIZED OPERATIONS

Remarks by Capt. K. M. Tebo, USN

Following the presentation by Mr. Nakayama and Mr. Learn, Capt. Tebo called for suggestions and recommendations on decentralized computer operations. Various comments were made, with the majority favoring decentralization.

Capt. Tebo then outlined a plan for further exploring the feasibility of decentralized operations. SP 12 would send out a letter to the companies concerned to obtain their reactions to the proposal. In addition, LMSD and Sperry would supply information to SP as to whether they could double the suggested computer workloads and approximate costs. Capt. Tebo stressed that adoption of the proposal would require effective liaison between NORC, Dahlgren and Lockheed and Sperry computer centers. Such a plan, of course, does not affect the over-all SP responsibility or the individual contractors for accuracy of reporting and analyses of their respective areas of effort.

USE OF THREE-TIME ESTIMATES

Remarks by W. W. Haase, NASA

(formerly with SP 12)

Significant improvements in the application and utility of PERT have been made during the past year. These improvements have resulted from struggling with and solving the political, organizational, procedural and mechanical problems associated with implementation of the system. Because of the heavy workload associated with implementing a new system to a program as broad as the POLARIS program, the level of effort in actual analysis of the system has been comparatively low. Then too, we have a tendency to evaluate only the advantages and disadvantages of PERT by itself, instead of comparing it to alternative systems.

We have had several questions raised as to the merits of three time estimates versus a single time

estimate. I don't believe anyone is qualified to completely answer that question at this time. There has not been sufficient operating experience to provide adequate statistical data for a complete evaluation. This is particularly true since initial acceptance of the technique was rather poor and early operational examples have an extreme amount of political bias. However, I do have some data which SP 12 has been collecting as a part of its continuing program for evaluating the PERT system. I hope this data may be of interest to you, and more than anything else, hope that it may stimulate some interest in collecting more data of this type, and ultimately lead to some comprehensive analysis of the PERT concept, formulas, human factors, etc.

Our first approach to analyzing PERT was to develop trend information to show a comparison of successive PERT outlooks. Each time the outlook showed an improvement or slip in the expected date for accomplishment of a particular event, we tried to explain the reason for this change. Was it due to some management action—a delay of some component—etc? It is amazing how much can be learned about the operation of PERT from this exercise. Not only does it highlight time gained from timely management action; it also highlights cases where the contractor is not being completely honest with himself and the Navy. During the PERT seminar in Washington about a year ago, I presented examples of these trend curves or characteristic curves as we have been calling them. At that time I indicated that almost all examples reviewed at that time (approx. 26) followed one of two patterns as illustrated in figures 1 and 2 below.

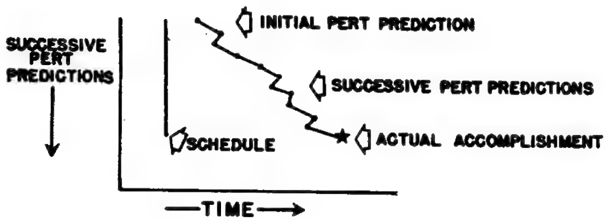


Figure 1. A slipping characteristic in which each successive PERT outlook was more pessimistic than the previous. I also pointed out that in almost each one of these cases there was very little spread in the three estimates and that most of them were symmetrical (i.e., 3 weeks + 1/2). Also in almost every one of these cases the actual accomplishment was even later than estimated two weeks prior to accomplishment. It is needless to say that PERT is buying very little over other systems for predicting when we get performance of that type. The reason for developing PERT in the first place was to provide a method of reflecting the uncertainties associated with development type tasks and to provide a more realistic outlook for their accomplishment than conventional systems have provided in the past. With a single estimate it would not be PERT since the PERT theory would be compromised.

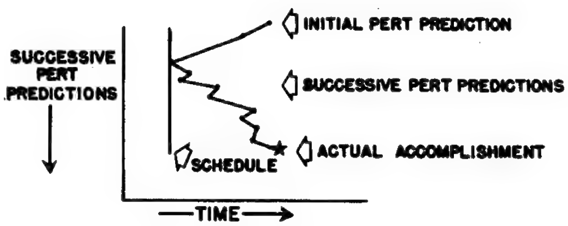


Figure 2. The other prominent characteristic was one in which the initial outlook was extremely pessimistic as compared to schedules. During the next two revisions the outlooks tended to improve and fall in line with schedules. This is how one would expect PERT to operate if problems were highlighted and corrective decisions were made. However, in many of these cases the improvements were not as a result of management decisions, but arbitrary revisions of the time estimates. The tendency was to fall back to the model estimate ± a small amount—thus removing the pessimism from the estimates. The cases were now similar to the figure 1 example and sure enough the same thing happened. As time went by, each successive PERT outlook had a more pessimistic outlook. It is surprising how close many of the actual accomplishments were to the initial pessimistic PERT outlook.

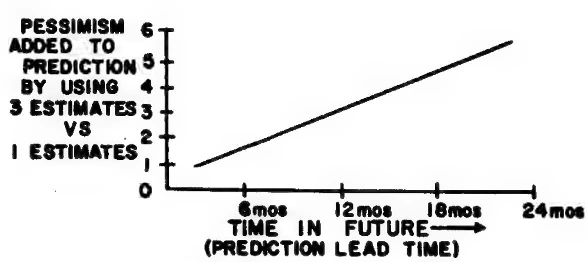


Figure 3. From this plot it would appear that on the average there was about 3 weeks (6%) more pessimistic outlook for events a year off when using 3 estimates than when using a single estimate. However, there was considerable dispersion of data above and below this line. Consequently, a more detailed analysis of a vertical cut of this data was made. This cut was made at about 6 months since this was the point at which the largest number of examples were available. A distribution curve of these examples was made by plotting them as shown in figure 4.

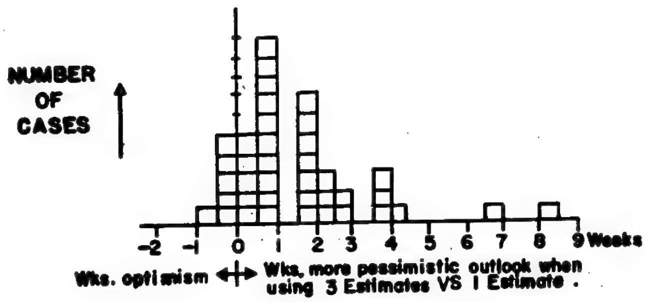


Figure 4. From figure 4 it can be seen that the most cases were about 1 week (4%) more pessimistic (out of 6 months) when using 3 estimates. However, this was using all cases past and present and I previously indicated some of the past examples left a lot to be desired. Crossing out those examples in which I had reason to believe PERT was not being honestly used as a management tool resulted in a distribution as shown in figure 5.

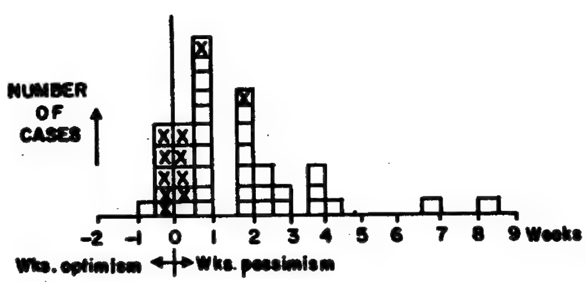


Figure 5. Notice that almost all examples eliminated for the reasons indicated above were on the optimistic or only slightly pessimistic side of the distribution, and that eliminating these cases made the difference between using 3 estimates versus a single estimate more significant. I believe that this is very definitely due to estimators loosening up on their estimates as they become convinced that the Navy is not using the technique as a club but as a 2-way management tool.

During the past year the acceptance of PERT "above the table" planning concept has increased significantly. The number of cases like the type 1 and 2 examples no longer are the majority as was the case a year ago. Most examples still show a pessimistic outlook the first time around and then show improvement. The characteristic curves are similar to the initial part of the type 2 example except that improvement results from management decisions and not arbitrary revisions of time estimates. Pessimism is not removed and the outlooks do not then tend to slip—instead they oscillate back and forth as problems come up and corrective decisions are made.

After this initial cut at analyzing PERT outlook trends, we decided to make a more comprehensive study to determine *how much* was being gained by the use of three estimates. It is generally agreed that many of the major benefits derived from PERT result from the forced detailed planning. The planning aspects, however, could be derived with a single time estimate. So how much benefit is gained as a result of the planning aspect and how much additional is gained as a result of the three time estimates versus a single time estimate?

We proceeded to review existing and completed networks to arrive at some sort of an answer. The first assumption made was that if a single time estimate was used it would be the modal estimate. This assumption can be debated depending on internal planning philosophies. However, based on the definition of the modal estimate and most common practices being used in the development of the estimate, there is good justification for this assumption. We then hand calculated the outlooks for each of the networks using a single (modal) time estimate for the activities and compared this outlook to the computer outlook based on three time estimates.

In all but 6 out of 4 examples the outlook based on 3 estimates was more pessimistic than that based on a single time estimate. As one might expect, the further off in the future that the event is, the more pessimism would be reflected. This was borne out by plotting the increased amount of pessimism versus time in the future. The trend of the data was as illustrated in figure 3.

Similar studies have also been made to relate the modal and expected estimates for accomplishment to scheduled dates and schedule revisions. This becomes extremely complex and it is too early to quote any definite relationships. However, there does appear to be an advantage in using 3 estimates. Since pessimism is reflected in almost all cases, it forces tightening of internal schedules to meet the contract date.

I know I haven't satisfactorily answered the question of 3 time estimates versus a single estimate. As I said earlier, I don't believe sufficient data is available at this time to make a complete evaluation. However, the data presented does give some quantitative feel for the difference between using 3 estimates versus a single estimate. This difference is significant in a program like the POLARIS program where time is at a premium. The data does, however, stimulate even further questions about the PERT concept, formulas, human factors, etc. Collection and analysis of operating data will serve to answer these questions and lead to further improvements in the technique.

L.M.S.D. - POLARIS MISSILE SYSTEM

PERT WORK FLOW PLAN

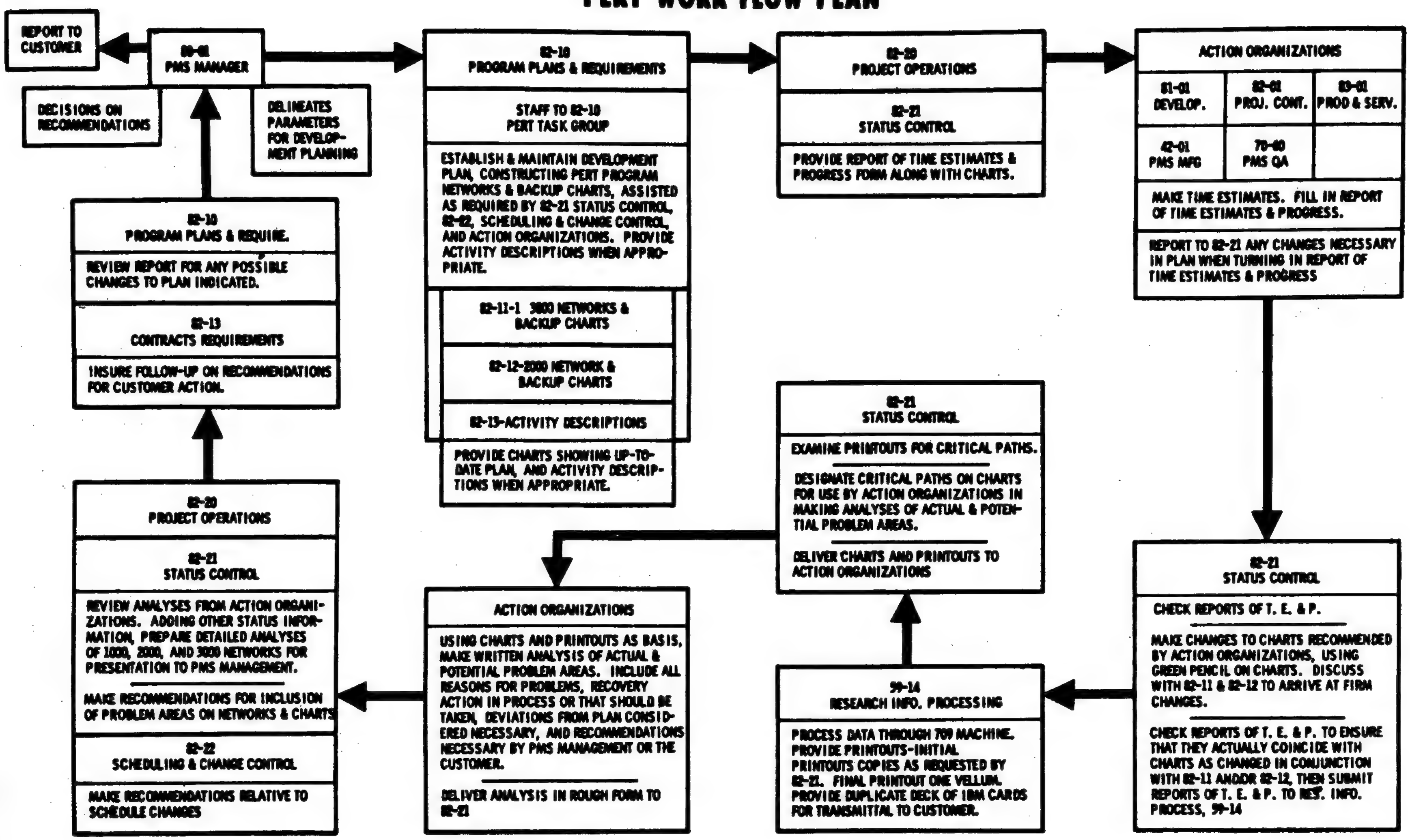


EXHIBIT 1

NETWORK Development

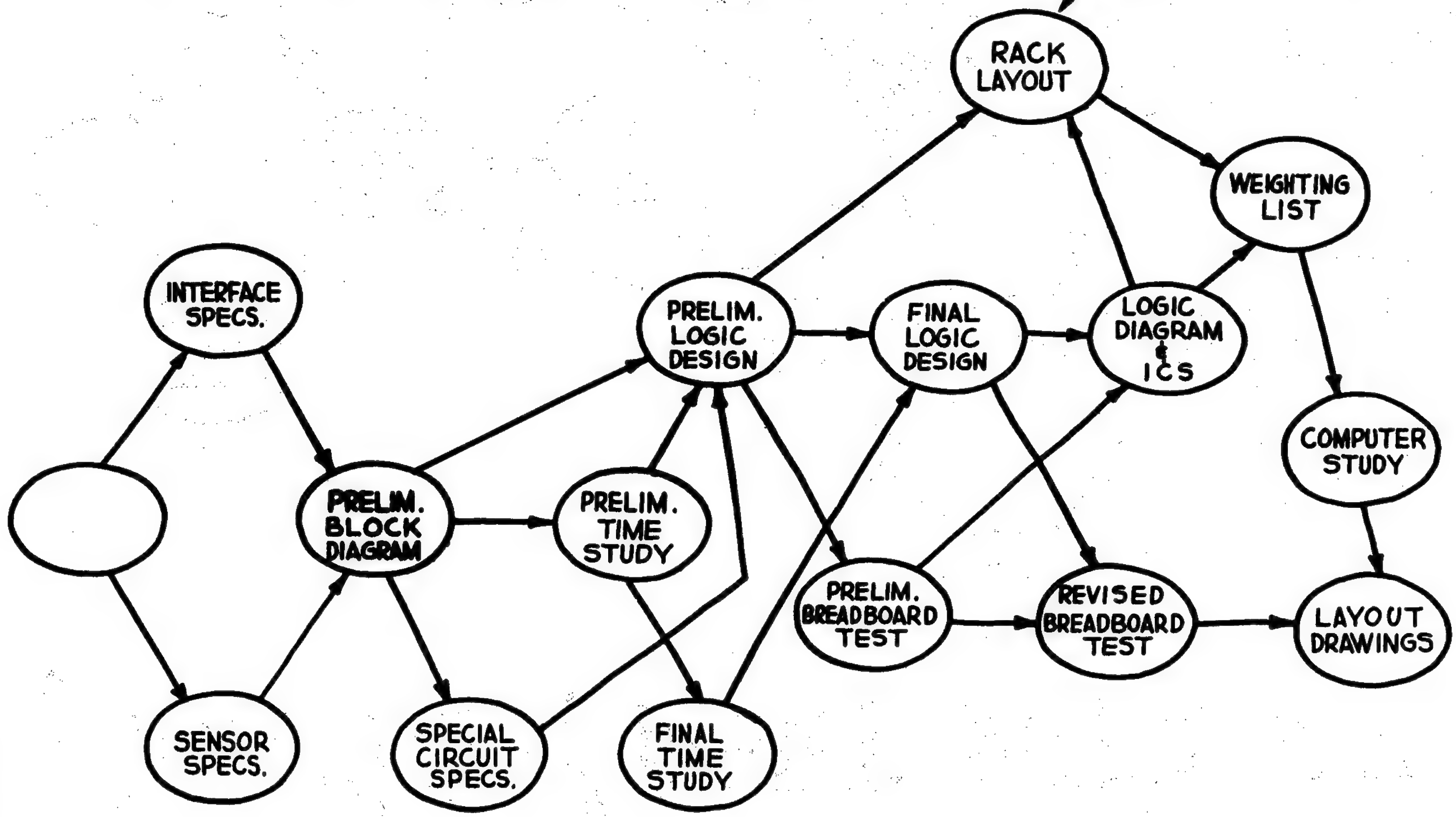


EXHIBIT 2

Completed PERT NETWORK

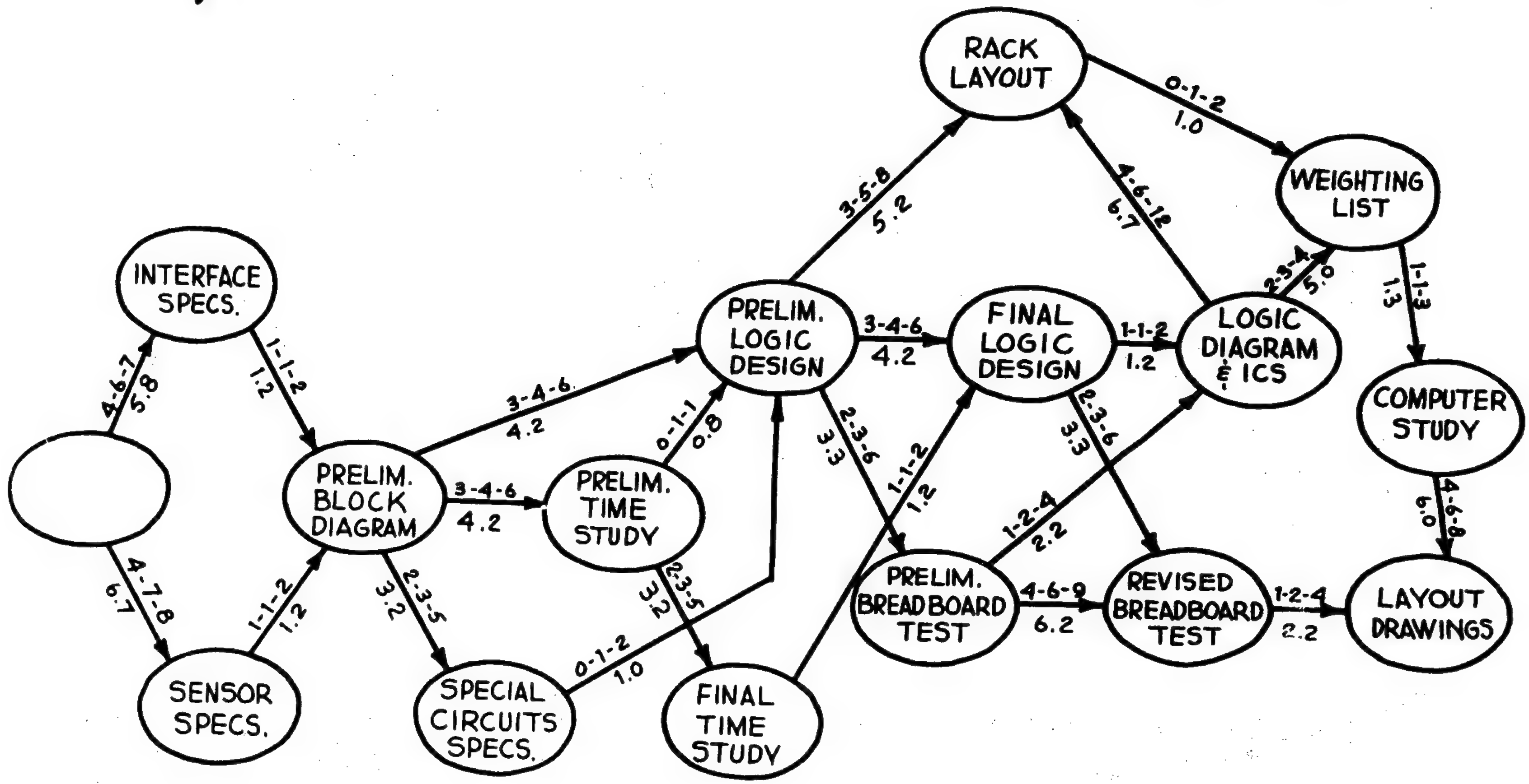


EXHIBIT 3

PERT ANALYSIS

NETWORK NUMBER 99-99-99

REFERENCE DATE 1-14-60

ANALYSIS DATE 1-14-60

EVENT NUMBER	EARLIEST EXPECTED TIME	LATEST EXPECTED TIME	EVENT SLACK	SCHEDULE	PROB. OF MEETING SCHEDULE	SCHEDULE SLACK
5	60.3	60.3	.0			
1	56.1	55.0	- 1.1	55	.44	- 1.1
2	43.6	42.5	- 1.1			
6	36.4	55.0	18.6			
3	37.8	36.7	- 1.1			
30	11.8	44.2	32.4			
4	37.8	36.7	- 1.1	30	.04	- 7.8
19	27.5	26.4	- 1.1			
8	27.7	36.5	8.8			
29	11.8	36.7	24.9			
20	22.3	21.2	- 1.1			
7	24.2	36.5	12.3			
12	26.9	35.7	8.8			
10	23.9	35.7	11.8			
9	21.9	35.7	13.8			
13	23.4	35.7	12.3			
14	21.9	30.7	8.8			
16	21.9	33.7	11.8			
17	21.9	34.2	12.3			
18	20.4	29.2	8.8			
21	20.1	28.9	8.8	22	.77	1.9
22	19.2	28.7	9.5			
36	17.1	16.0	- 1.1			
24	14.1	27.5	13.4			
23	18.0	27.5	9.5			
26	14.1	24.9	10.8			
37	15.6	14.5	- 1.1			
27	15.0	24.5	9.5			
28	11.8	10.7	- 1.1	12	.54	.2
34	9.5	8.4	- 1.1			
32	8.3	8.4	.1			
31	7.5	8.4	.9			
35	2.3	1.2	- 1.1			
38	1.0	.4	- .6			
39	.0	1.1	- 1.1			

TOTAL NUMBER OF EVENTS 35

TOTAL NUMBER OF ACTIVITIES 54

EVENTS COMPOSING CRITICAL PATH

39, 35, 34, 28, 37, 36, 20, 19, 4, 3, 2, 1,

OBJECTIVE EVENT NUMBER	EARLIEST EXPECTED TIME	EARLIEST EXPECTED TIME VARIANCE
5	60.3	36.93
1	56.1	43.18

EXHIBIT 4

KEY PERSONNEL UTILIZATION REPORT

TIME	MAN A	A	A	A	
					----------------(up to 30 man codes)
1		1	1	1	
2	1	1	1	1	
3	2	1	1	1	(numbers indicate number of activities on which man is simultaneously engaged each week)
4	2	2	1		
5	2	2			
6	1	3		1	
7	1	3	1	2	
8		1	1	2	
		1	1	2	

(99)

% aa bb cc dd (percent of total time each man occupied)

SKILL UTILIZATION REPORT

TIME	SKILL CODE A	B	C	D	E
1	2				
2	2	1			
3	3	1			3
4	3	4	1		3
5	3	4	1		2
6		4	1		2
7		4	1		1
8		3		1	1
		3		1	
				1	

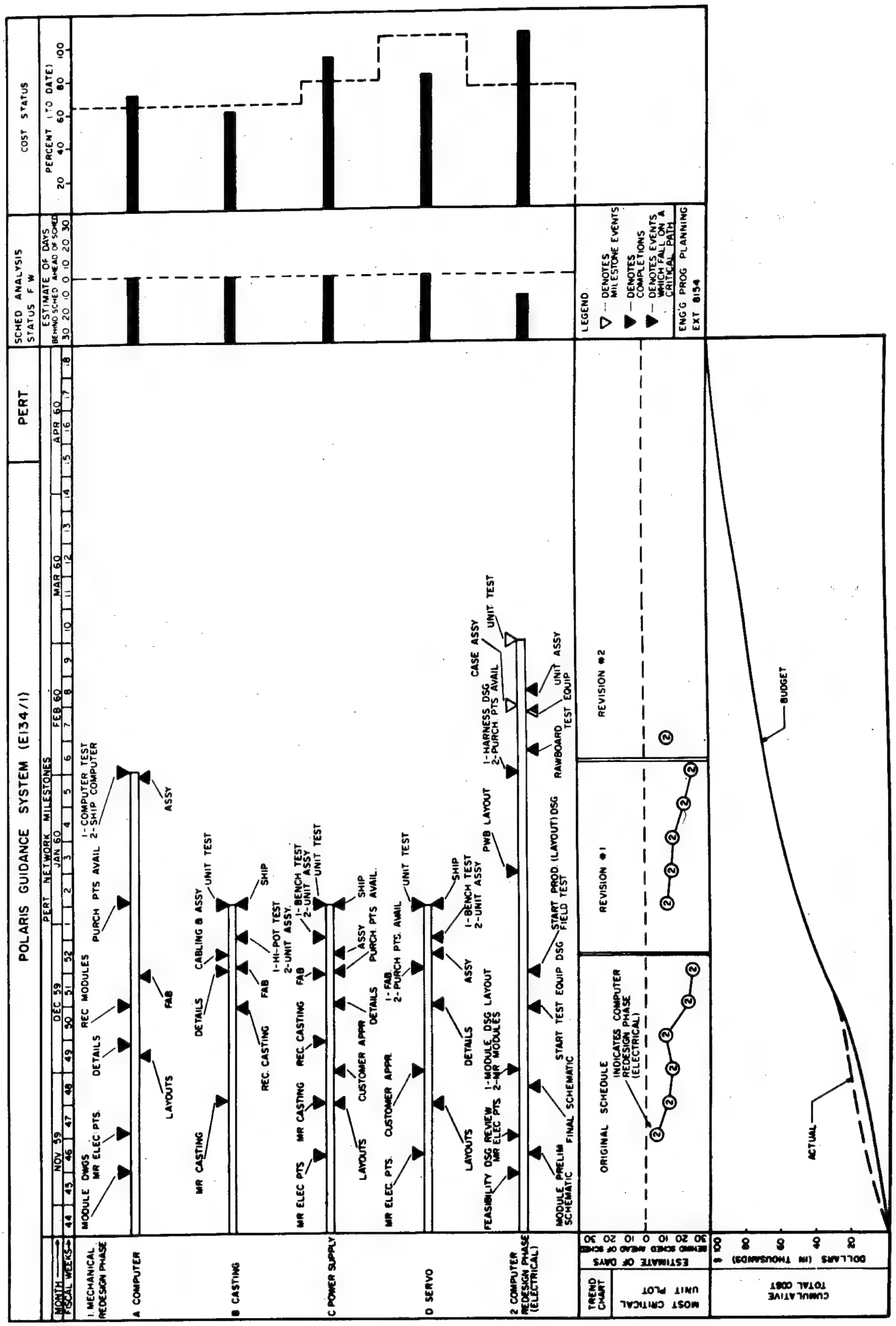
(Numbers indicate how many men of each skill are being used each week)

% aa bb cc dd ee (percent utilization of each skill)

SCHEDULE-COST REPORT

		PCT UTIL.	COST
ENGINEERING:	ELECTRICAL DEV.	______%	$______
	MECHANICAL DEV.	______	______
	PROD. DESIGN	______	______
	TOTAL	______	______
TECHNICIAN:	ELECTRICAL	______	______
	MECHANICAL	______	______
	TEST	______	______
	TOTAL	______	______
TOTAL PERSONNEL		______	______
ASSOCIATE COSTS			______
GRAND TOTAL			______

EXHIBIT 5



POLARIS GUIDANCE SYSTEM (E134/1)
PERT
SCHED ANALYSIS STATUS F W
COST STATUS
PERCENT (TO DATE)
ESTIMATE OF DAYS
PERT NETWORK MILESTONES
MONTH
FISCAL WEEKS
NOV 59
DEC 59
JAN 60
FEB 60
MAR 60
APR 60
1. MECHANICAL REDESIGN PHASE
A COMPUTER
B CASTING
C POWER SUPPLY
D SERVO
2 COMPUTER REDESIGN PHASE (ELECTRICAL)
TREND CHART
MOST CRITICAL UNIT PLOT
CUMULATIVE TOTAL COST
DOLLARS (IN THOUSANDS)
ORIGINAL SCHEDULE
REVISION #1
REVISION #2
BUDGET
ACTUAL
LEGEND
DENOTES MILESTONE EVENTS
DENOTES COMPLETIONS
DENOTES EVENTS WHICH FALL ON A CRITICAL PATH
ENG'G PROG PLANNING
EXT 8154

EXHIBIT 6

F1

COMPUTER NUMBER (Do Not Use)	TEMP JOB NO.	JOB DESCRIPTION	CYCLE TIME (Days)	PREVIOUS JOB(S)	MAN TYPE	MAN-DAYS REQ'D	BUY COST $
0220000001	1	CONTRACTOR NEGOTIATIONS	22	0	7200	30	
0220000002	2	DESIGN + LAYOUT	5.5	1	7300	20	
0220000003	3	DESIGN REVIEW + APPROVAL	10.5	2	7100	5	
0220000004	4	ESTABLISH WELDING PROCEDURE	9.0	3	7600	10	
0230000001	5	ESTAB. MATERIAL VENDOR LIST	10	0	7200	2	
0260000001	6	RELEASE ALL DETAIL DWGS.	50	1, 3	7300	150	
0260000002	7	MATERIAL RELEASE	50	6	7300	20	
0260000003	8	PROCURE ALL MATERIAL	50	5, 7	7500		4500
0270000001	9	DESIGN PN136071 WELDING FIXTURE	15	4	7300	8	
0270000002	10	PROCURE PN136071 WELDING FIXTURE	5	9	7500		12250
0270000003	11	FINAL ASSEMBLY OF PN 136070	10	12,13,14,15	7640 7653 7651	20 5 [illegible]	
0271000001	12	FABRICATE + ASSEMBLE PN 136071	20.5	8, 10	7400 7600	30 10	
0272000001	13	FABRICATE PN 136072	30	8	7400	15	
0273000001	14	FABRICATE PN 136073	5	8	7400	5	
0274000001	15	FABRICATE PN 136074	5	8	7400	5	

EXHIBIT 7

SCHEDULE EVALUATION AND CONTROL

704 INPUT SHEET-1

PROBLEM: SAMPLE CONTROL SCHEDULE — LOG WA 672

CODER: JONES — DATE: 11/6/59 — PAGE 1 OF 2

JOB DESCRIPTION	LOCATION	OPERATION	JOB NUMBER	PREVIOUS JOB	EST CYCLE TIME-DAYS	ACTUAL TIME DAYS	PART NUMBER	DEPT	MAN TYPE	MAN-DAYS	COST - OTHER THAN LABOR
CONTRACTOR NEGOTIATIONS		DEC	0220000001	0000000000	022.0			7200	01	30.0C	.
		DEC									.
DESIGN & LAYOUT		DEC	0220000002	0220000001	005.5		136070	7300	10	20.0C	.
		DEC									.
DESIGN REVIEW & APPROVAL		DEC	0220000003	0220000002	010.5			7100	01	05.0C	.
		DEC									.
ESTABLISH WELDING PROCEDURE		DEC	0220000004	0220000003	009.0			7600	70	10.0C	.
		DEC									.
ESTABLISH MATERIAL VENDOR LIST		DEC	0230000001	0000000000	010.0			7200	01	02.0C	.
		DEC									.
RELEASE ALL DETAIL DWGS.		DEC	0260000001	0220000001	050.0			7300	10	150.C	.
		DEC	0260000001	0220000003	050.0			7300			.
		DEC									.
MATERIAL RELEASE		DEC	0260000002	0260000001	050.0			7300	10	20.0C	.
		DEC									.
PROCURE ALL MATERIAL		DEC	0260000003	0230000001	050.0			7500	95	C	4500.
		DEC	0260000003	0260000002	050.0			7500			.
		DEC									.
DESIGN PN136071 WELDING FIXTURE		DEC	0270000001	0220000004	015.0			7300	10	08.0C	.
		DEC									.
PROCURE PN136071 WELDING FIXTURE		DEC	0270000002	0270000001	005.0			7500	95	C	12250.
		DEC									.
		DEC									.
		DEC									.
		DEC									.

EXHIBIT 8

```
                                 SAMPLE PROGRAM
                                 PROJECT NO 02
                                 SCHEDULE NO 1 - ORIGINAL SCHEDULE

                          START DATE  EVALUATION DATE  END DATE
                           11091959        11091959

                          END DATE - REQUIRED END DATE =        0.00

PART NO     JOB NO          JOB  DESCRIPTION        DEPT ENGINEERS
                                                         RESCHEDULE
                                                         START  END

             0220000001CONTRACTOR NEGOTIATIONS    72001109912109    22.0         22.0
2             220000001   11091959      12101959    -12101959
1             220000001          0           0.                          0.
                                                                 22.00
 136070      0220000002DESIGN AND LAYOUT           73001210912189     5.5          5.5
2             220000002   12101959      12181959    -12181959            0.
1             220000002   220000001          0.                      5.50
             0220000003DESIGN REVIEW AND APPROVAL710012189 1050    10.5         10.5
2             220000003   12181959       1051960    -1051960             0.
1             220000003   220000002          0.                     10.50
             0220000004ESTAB WELDING PROCEDURE    7600 1050 1180     9.0          9.0
2             220000004    1051960       1181960     7221960             0.
1             220000004   220000003          0.                      9.00
             0230000001ESTAB MATERIAL VENDR LIST  72001109911239    10.0         10.0
2             230000001   11091959      11231959     5251960             0.
1             230000001          0           0.                     10.00
             0260000001RELEASE ALL DETAIL DWGS    7300 1050 3160    50.0         50.0
2             260000001    1051960       3161960    -3161960            .0.
1             260000001   220000001          0.                     50.00
1             260000001   220000003          0.                     50.00
             0260000002MATERIAL RELEASE           7300 3160 5250    50.0         50.0
2             260000002    3161960       5251960    -5251960             0.
1             260000002   260000001          0.                     50.00
             0260000003PROCURE ALL MATERIAL       7500 5250 8190    15.0         15.0
2             260000003    5251960       8191960    -8191960             0.
1             260000003   220000001          0.                     50.00
1             260000003   230000001          0.                     50.00
1             260000003   260000002          0.                     50.00
 136071      0270000001DES PN136071 WELD FIXTURE 7300 1180 2080    15.0         15.0
2             270000001    1181960       2081960     8261960             0.
1             270000001   220000004          0.                     15.00
 136071      0270000002PROC PN136071 WELD FIXTURE7500 2080 2150     5.0          5.0
2             270000002    2081960       2151960     9021960             0.
1             270000002   270000001          0.                      5.00
 136070      0270000003FINAL ASSEMBLY             76001003010170    10.0         10.0 M
2             270000003   10031960      10171960    -10171960            0.
1             270000003   260000003          0.                     10.00
```

OVERALL PROGRAM STATUS "INDICATOR" (DAYS LATE OR EARLY)

ORIGINAL SCHEDULE CYCLE-DAYS

CURRENT PROMISED SCHEDULE

START DATE END DATE CYCLE (DAYS)

DEPT. OR PERSON RESPONSIBLE

COMPUTED SCHEDULE (START + END DATE)

OPEN JOB "INDICATOR"

COMPUTED CYCLE TIME-DAYS

PROCURE MATERIAL DEPENDS ON THESE JOBS

CRITICAL JOB "INDICATOR"

MAJOR MILESTONE-

LATEST DATE JOB CAN BE COMPLETED WITHOUT AFFECTING PROGRAM END DATE

EXHIBIT 9

SAMPLE CONTROL SCHEDULE PROGRAM COSTING

PLANNING PHASE - OPEN SCHEDULE

COMPLETE LIST OF PROGRAM TASK COST

JOB NO	DEPT	MAN	AVG NO. MEN	COSTS OTHER THAN LABOR	START DATE	END DATE	CYCLE DAYS	TIME WEEKS	MANPOWER M-DAYS	MANPOWER M-WEEKS	LABOR COST
220000001	7200	1	1.4	0.	11091959	12101959	22.0	4.4	30.0	6.00	2316.00
220000002	7300	10	3.6	0.	12101959	12181959	5.5	1.1	20.0	4.00	1752.00
220000003	7100	1	0.5	0.	12181959	1051960	10.5	2.1	5.0	1.00	386.00
220000004	7600	70	1.1	0.	1051960	1181960	9.0	1.8	10.0	2.00	681.60
230000001	7200	1	0.2	0.	11091959	11231959	10.0	2.0	2.0	0.40	154.40
260000001	7300	10	0.3	0.	1051960	3161960	50.0	10.0	15.0	3.00	1314.00
260000002	7300	10	0.4	0.	3161960	5251960	50.0	10.0	20.0	4.00	1752.00
260000003	7500	95	0.	4500.	5251960	8191960	50.0	10.0	0.	0.	0.
270000001	7300	10	0.5	0.	1181960	2081960	15.0	3.0	8.0	1.60	700.80
270000002	7500	95	0.	12250.	2081960	2151960	5.0	1.0	0.	0.	0.
270000003	7600	40	2.0	0.	10031960	10171960	10.0	2.0	20.0	4.00	1190.40
270000003	7600	53	0.5	0.	10031960	10171960	10.0	2.0	5.0	1.00	455.60
270000003	7600	51	0.2	0.	10031960	10171960	10.0	2.0	2.0	0.40	140.16
271000001	7400	60	1.5	0.	8191960	9201960	20.5	4.1	30.0	6.00	1785.60
271000001	7600	40	0.5	0.	8191960	9201960	20.5	4.1	10.0	2.00	595.20
272000001	7400	60	0.5	0.	8191960	10031960	30.0	6.0	15.0	3.00	892.80
273000001	7400	60	1.0	0.	8191960	8261960	5.0	1.0	5.0	1.00	297.60
274000001	7400	60	1.0	0.	8191960	8261960	5.0	1.0	5.0	1.00	297.60

EXHIBIT 10

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SHEET 1 OF 1

WEEKLY ENGINEERING REPORT ON JOB COMPLETIONS, CANCELLATIONS, ADDITIONS AND RESCHEDULES

PROJECT TITLE: SAMPLE PROGRAM – SCHEDULE NO. 3

REPORTING ENGINEER (Signature): ______ DEPT. NO.: ______

NOTE: IF NO CHANGE IN JOB STATUS CHECK HERE: ☐

PROJECT NO.: 02

REPORT NO.: A-2

DATE: 3/15/60

PROJ. ENGR.: ______

JOB COMPLETIONS AND CANCELLATIONS

JOB NUMBER	JOB DESCRIPTION	PART NUMBER	DATE COMPLETED	DATE CANCELED	(FOR USE BY PROGRAMS CONTROL ONLY) END DAY #	START DATE	START DAY #	CYCLE (DAYS)	
0260000001	RELEASE ALL DETAIL DWGS		2/18/60		523	12/22/59	483	40	
0270000002	PROCURE WELD FIXTURE	136071		3/15/60					

NEW JOB ADDITIONS AND OLD JOB RESCHEDULES

ASSIGNED JOB NO.	JOB DESCRIPTION	PART NUMBER	DEPT. RESPONSIBLE	CHECK ONE: OLD JOB	NEW JOB	SCHEDULE: START DATE	END DATE	WRK'NG CYCLE (DAYS)	PREVIOUS JOB NO.	FOLLOWING JOB NO.	
0270000004	PROC. MODIFIED WELD FIXTURE	136071	7500		✓	11/4/60	1/5/61	40	0270000001	0271000001	
0275000001	FABRICATE	136075	7400		✓	11/14/60	1/26/61	50	0260000003	0270000003	
0260000003	PROCURE ALL MATERIAL		7500	✓		9/1/60	11/14/60	50			
0270000001	DESIGN WELD FIXTURE	136071	7300	✓		9/1/60	11/4/60	45			
0270000003	FINAL ASSEMBLY	136070	7690	✓		2/3/61	3/6/61	20			

EXHIBIT 11

COMPUTED SCHEDULE BASED ON PROMISED CYCLE TIMES AND JOB SEQUENCE.

```
SAMPLE PROGRAM

PROJECT NO 02

SCHEDULE NO 3 -OPEN

START DATE   EVALUATION DATE   END DATE
 11101959        3151960
```

DATE THIS SCHEDULE WAS COMPUTED

```
END DATE - REQUIRED END DATE =        0.

                                        COMPLETION CODE
                                          COMPLETE = 1.
                                              LATE = ***
```

COMPUTED "OPEN" SCHEDULE - REPRESENTS CURRENT SCHEDULE UNLESS CHANGES ARE MADE.

CURRENT PROMISED SCHEDULE AND CYCLE TIME

```
        0220000001CONTRACTOR NEGOTIATIONS     72001109912089    20.0        22.0
2         220000001     11091959     12081959    -12081959           1.
1         220000001            0        20.00                20.00
 136070 0220000002DESIGN AND LAYOUT           73001208912159     5.0         5.5
2         220000002     12081959     12151959    -12151959           1.
1         220000002     220000001        5.00                 5.00
        0220000003DESIGN REVIEW AND APPROVAL71001215912229     5.0        10.5
2         220000003     12151959     12221959    -12221959           1.
1         220000003     220000002        5.00                 5.00
        0220000004ESTAB WELDING PROCEDURE     7600 1050 1180     9.0         9.0
2         220000004     12221959      3151960      5061960          ***
1         220000004     220000003       57.00                57.00
        0230000001ESTAB MATERIAL VENDOR LIST72001109912179    27.0        10.0
2         230000001     11091959     12171959      5131960           1.
1         230000001            0        27.00                27.00
        0260000001RELEASE ALL DETAIL DWGS     7300 1050 2180    40.0        50.0
2         260000001     12221959      2181960     -2181960           1.
1         260000001     220000001       40.00                40.00
1         260000001     220000003       40.00                40.00
        0260000002MATERIAL RELEASE            7300 3160 5250    50.0        50.0
2         260000002      2181960      5131960     -5131960           0.
1         260000002     260000001       17.00                60.00
        0260000003PROCURE ALL MATERIAL        7500 901011140    50.0        15.0
2         260000003      5131960      8091960     -8091960           0.
1         260000003     220000001          0.                50.00
1         260000003     230000001          0.                50.00
1         260000003     260000002          0.                50.00
 136071 0270000001DES PN136071 WELD FIXTURE 7300 901011040    45.0        15.0
2         270000001      3151960      5171960      7121960           0.
1         270000001     220000004         ***                45.00
 136071 0270000002PROC PN136071 WELD FIXTURE7500 2080 3150     0.0         5.0 N
2         270000002      5171960      5171960      9211960           1.
```

ORIGINAL CYCLE TIME

ACTUAL COMPLETION DATE

JOB COMPLETED "INDICATOR"

LATE JOB "INDICATOR"

ACTUAL CYCLE TIME

CYCLE TIME TO DATE

TOTAL EXPECTED CYCLE TIME

CANCELLED JOB "INDICATOR"

POTENTIAL TROUBLE "INDICATOR" THIS JOB FOLLOWS A LATE JOB.

EXHIBIT 12

COMPUTED SCHEDULE REPRESENTING JOB SCHEDULES REQUIRED TO MEET OVERALL PROGRAM TARGET DATE

```
SAMPLE PROGRAM
PROJECT NO 02
SCHEDULE NO 3 - CLOSED                         PROGRAM TARGET DATE

START DATE   EVALUATION DATE   END DATE        PROGRAM IS CURRENTLY 22
 11091959       3151960        10171960        DAYS LATE RELATIVE TO
DATE SCHEDULE WAS COMPUTED                     TARGET DATE UNLESS ACTION
END DATE - REQUIRED END DATE =     22.00       IS TAKEN

PART NO    JOB NO.     JOB  DESCRIPTION      DEPT ENGINEERS
COMPUTED "CLOSED" SCHEDULE WHICH                RESCHEDULE
REPRESENTS THE SCHEDULE WHICH MUST BE
MET TO MEET PROGRAM TARGET DATE.                START  END
         0220000001CONTRACTOR NEGOTIATIONS   72001109912089    20.0      22.0
2          220000001    11091959    12081959  -12081959            1.
1          220000001           0       20.00            20.00          ORIGINAL
136070   0220000002DESIGN AND LAYOUT ACTUAL  73001208912159    5.0       CYCLE TIME 5.5
                              COMPLETION DATE
2          220000002    12081959    12151959  -12151959            1  JOB
1          220000002    220000001       5.00 ACTUAL DAYS   5.00    COMPLETED
                                             REQUIRED                "INDICATOR"
         0220000003DESIGN REVIEW AND APPROVAL71001215912229    5.0       10.5
2          220000003    12151959    12221959  -12221959            1.
1          220000003    220000002       5.00            5.00
         0220000004ESTAB WELDING PROCEDURE   7600 1050 1180    9.0       9.0
2          220000004    12221959     3151960   4281960          *** LATE JOB
1          220000004    220000003      57.00            57.00       "INDICATOR"
         0230000001ESTAB MATERIAL VENDOR LIST72001109912179    27.0      10.0
2          230000001    11091959    12171959   5051960             1.
1          230000001           0       27.00            27.00
         0260000001RELEASE ALL DETAIL DWGS   7300 1050 2180    40.0      50.0
2          260000001    12221959     2181960  -2181960             1.
1          260000001    220000001      40.00 CRITICAL JOB  40.00
1          260000001    220000003      40.00 "INDICATOR"   40.00
         0260000002MATERIAL RELEASE          7300 3160 5250    50.0      50.0
2          260000002    2181960      5051960  -5051960             0.
1          260000002    260000001      17.00            54.19
         0260000003PROCURE ALL MATERIAL      7500 901011140    50.0      15.0
2          260000003    5051960      7071960  -7071960             0.  CURRENT
1          260000003    220000001         0.            43.25         PROMISED
1          260000003    230000001         0.            43.25         SCHEDULE +
1          260000003    260000002         0.            43.25         CYCLE TIME
136071   0270000001DES PN136071 WELD FIXTURE 7300 901011040    45.0      15.0
2          270000001    3151960 "TROUBLE 5091960   6231960         0.  ORIGINAL
1          270000001    220000004 INDICATOR" ***  CURRENT  38.92       CYCLE TIME
                                                  PROMD. CYCLE 2
136071   0270000002PROC PN136071 WELD FIXTURE7500 2080 3150    0.0       5.0 N
2          270000002    5091960      5091960   8261960             1.
1          270000002    270000001         0.            0.
136070   0270000003FINAL ASSEMBLY            7600 2031 3061    20.0      10.0 M
2          270000003    9221960     10171960  -10171960            0.
1          270000003    260000003 FINAL ASY. 0.         17.30   TARGET
1          270000003    271000001 DEPENDS    0. NOTE THAT 17.30 MILESTONE
1          270000003    272000001 ON THESE   0. THIS DATE 17.30 "INDICATOR"
1          270000003    273000001 JOBS.      0. AGREES WITH 17.30
1          270000003    274000001            0. TARGET DATE 17.30
1          270000003    275000001            0.         17.30
```

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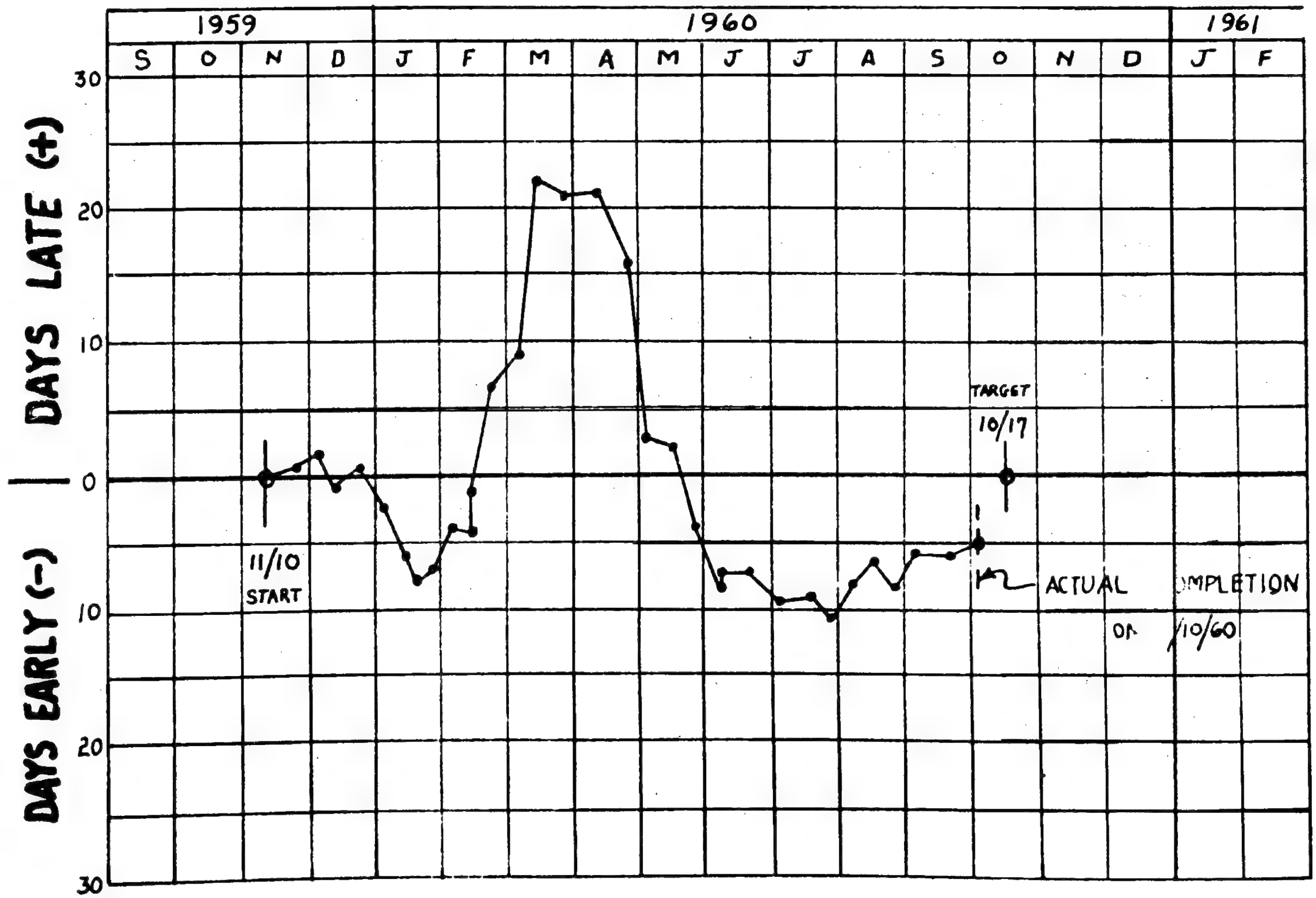
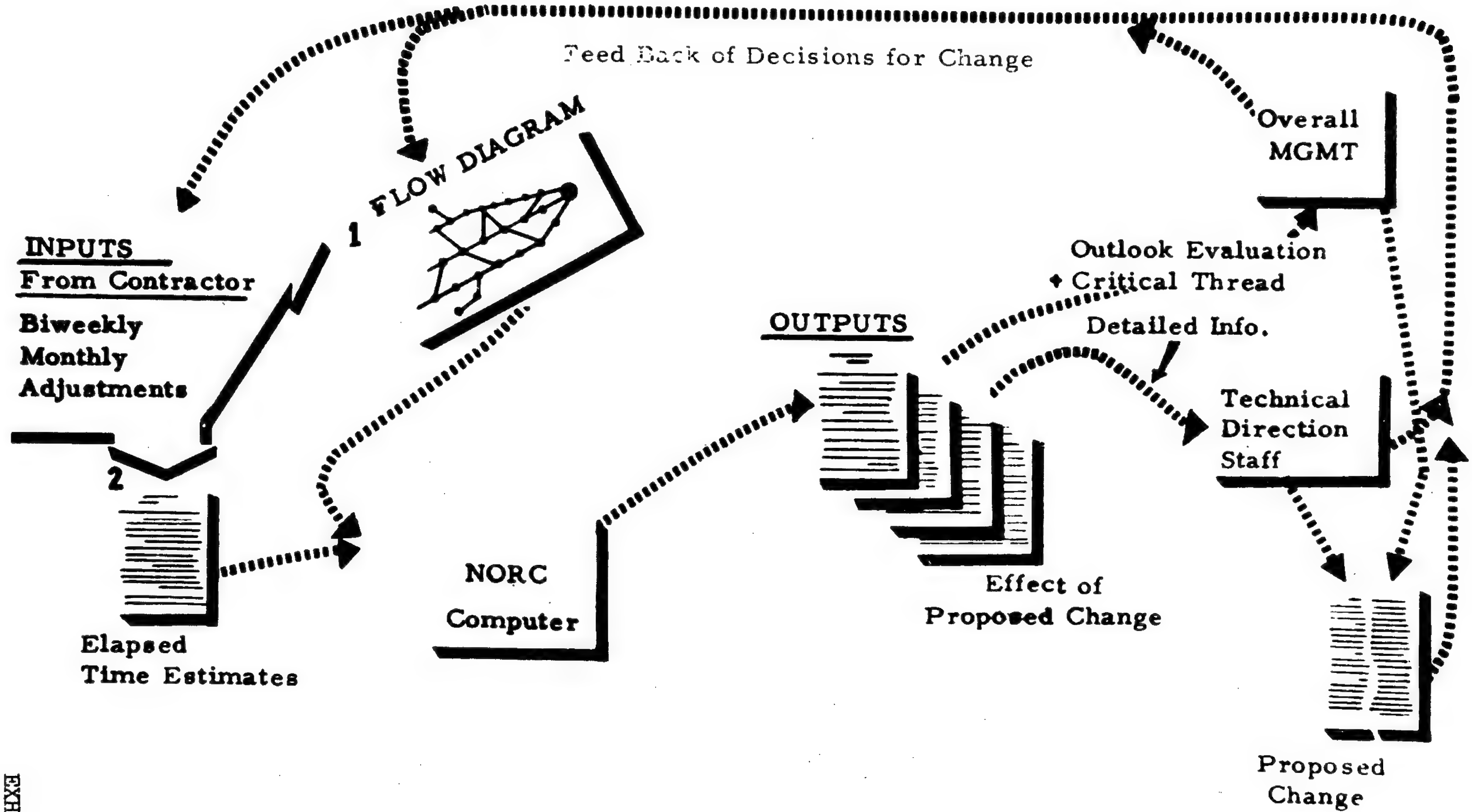
MONITORING REPORT - PROGRAM SUMMARY

SAMPLE PROGRAM - FINAL ASSEMBLY PN 136070



PERT SYSTEM IN OPERATION



SIMULATION FOR DECISION

EXHIBIT 15

Decentralized PERT Computer Operations

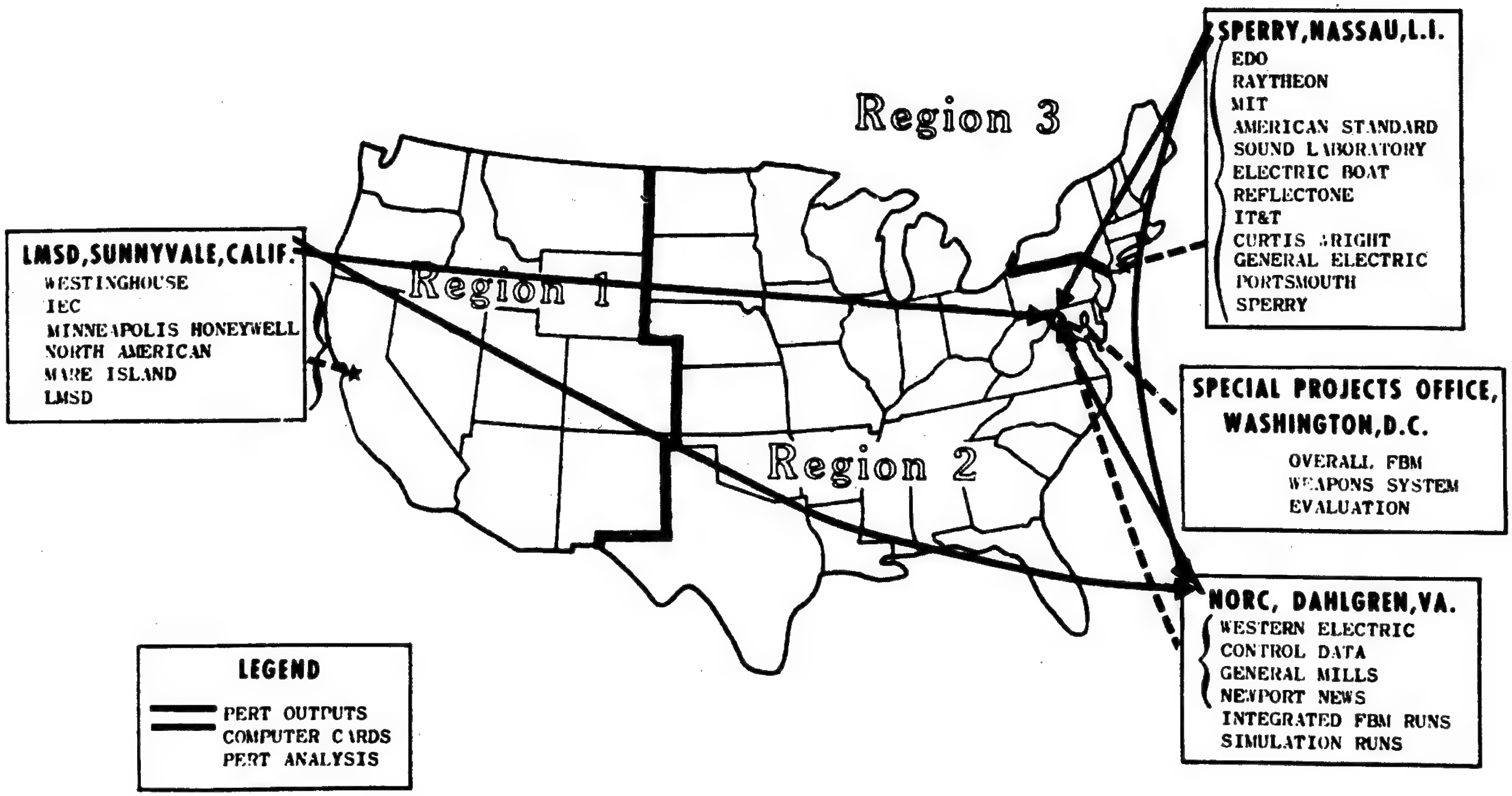


EXHIBIT 16

PROCEEDINGS OF THE P E R T COORDINATION TASK GROUP MEETING

16-17 AUGUST 1960

LMSD
PALO ALTO, CALIFORNIA

Sp-1211: JBB: sg
5000/4

From: Director, Special Projects

To : Distribution

Subj: PERT Coordination Task Group Meeting, 16-17 August 1960

Encl: (1) Proceedings of the PERT Coordination Task Group Meeting; 3rd Meeting, 16-17 August 1960

1. The summary minutes of the proceedings for subject meeting are provided as enclosure (1).

K. M. Tebo

K. M. TEBO
By direction

Distribution:
(See attached)

ROSTER OF ATTENDEES
at PERT Coordination Task Group Meeting

16-17 August 1960

Amico, Mr. G. V.	U.S. Naval Training Device Center, Port Washington
Archibald, Mr. Russell D.	Aerojet-General Corp., Sacramento, Calif.
Bajorski, Mr. Anthony	EDO Corp., College Point, New York
Blitch, Mr. J. D.	Lockheed MSD, Sunnyvale, California
Bogdan, Mr. Albert	General Electric, Pittsfield, Massachusetts
Bonquet, Mr. John	Minneapolis-Honeywell, Duarte, Calif.
Bryant, Mr. Thomas D.	Librascope, Glendale, California
Burnham, Mr. Donald H.	Westinghouse, Sunnyvale, California
Burnside, Mr. C. J.	Lockheed MSD, Sunnyvale, California
Cariski, Mr. S. A.	SPOTR, Syosset, New York
Carter, Dr. Richard P.	Allegany Ballistics Lab., Cumberland, Md.
Ciochetto, Mr. J. J.	Librascope, Glendale, California
Dick, Mr. E. O.	Westinghouse, Sunnyvale, California
Dunipace, Mr. K. R.	M. I. T., Cambridge, Massachusetts
Erickson, Mr. Robt. S.	Control Data, Minneapolis, Minnesota
Froncello, Mr. R. E.	Raytheon, Waltham, Massachusetts
Geri, Ltjg. Don	SP-27, Washington, D. C.
Goff, Mr. Douglas S.	Sperry Gyroscope, Syosset, New York
Gould, Mr. Ralph D.	General Electric, Pittsfiled, Massachusetts
Hall, Mr. Don	Lockheed MSD, Sunnyvale, California
Halzel, Mr. Isadore	M. I. T., Cambridge, Massachusetts
Hansen, Mr. B. J.	Lockheed MSD, Sunnyvale, California
Hodgkins, Mr. Walt	Lockheed MSD, Sunnyvale, California
Jenkins, Mr. Charles W.	Lockheed MSD, Sunnyvale, California
Kester, Mr. Waldo	AMC, Dayton, Ohio
Ketchum, Mr. Paul D.	BuWepsRep, Sunnyvale, California
Koch, Mr. J. G.	Lockheed MSD, Sunnyvale, California
Krauthamer, LCdr. R. J.	RINSMAT, Sunnyvale, California
Lasser, Mr. Dan	Lockheed MSD, Sunnyvale, California
Learn, Mr. Robt. N.	NORC, Dahlgren, Virginia
Lee, Mr. Joseph E.	BuWepsRep, Sunnyvale, California
Lindquist, Mr. Harris R.	Control Data, Minneapolis, Minnesota
Marshall, Mr. Robt. R.	Westinghouse, Sunnyvale, California
Nakayama, Mr. Yukio	Sp-12, Washington, D. C.
Nupp, Mr. Thomas A.	RCA, Camden, New Jersey
Patterson, Mr. W. B.	Allegany Ballistics Lab., Conberland, Md.
Pearson, Mr. C. C.	Lockheed MSD, Sunnyvale, California
Phelps, Mr. H. Sheldon	Aerojet-General Corp., Sacramento, Calif.
Reuter, Mr. Charles L.	BuShips, Washington, D. C.
Rich, Mr. Glen K.	Hughes, Culver City, California
Ross, Mr. Thomas E.	Librascope, Glendale, California
Sager, Mr. Roland D.	Autonetics, Downey, California
Salzer, Mr. J. R.	Electric Boat Div., Groton, Connecticut
Savage, Mr. Paul P.	Minneapolis-Honeywell, Minneapolis, Minn.
Sciara, Mr. Don	Mare Island Naval Shipyard, Vallejo, Calif.
Sharpe, Mr. C. B.	Electric Boat Div., Groton, Connecticut
Sliney, Mr. James G.	Hughes, Culver City, California
Sloane, Mr. Alex P.	Nortronics, Norwood, Massachusetts
Smith, LCol. Daniel C.	AMC, Dayton, Ohio
Soth, Mr. George N.	Nortronics, Anaheim, California
Tebo, Capt. Kenneth M.	Sp-12, Washington D. C.
Turner, Mr. C.S.	Newport News Shipbldg. Corp., Newport News, Va.
Valiasek, Mr. John W.	General Electric, Pittsfield, Massachusetts
Van Dolson, Mr. George, Jr.	Mare Island Naval Shipyard, Vallejo, Calif.
Veccia, Ltjg. James E.	Sp-24, Washington, D.C.
Walsh, Mr. Tom	Mare Island Naval Shipyard, Vallejo, Calif.
Wasserman, Mr. Paul	Raytheon, Newport, Rhode Island
Welteroth, Mr. C. B.	Lockheed MSD, Sunnyvale, California
Williams, Mr. E. Kenneth	Sperry Gyroscope, Syosset, N.Y.
Williams, Mr. R. N.	RINSMAT, Sunnyvale, California
Young, Mr. Richard M. T.	Lockheed MSD, Sunnyvale, California

TABLE OF CONTENTS

INTRODUCTION

The third meeting of the PERT Coordination Task Group was opened on Tuesday, 16 August 1960, by Captain Kenneth M. Tebo, USN, Head, Program Evaluation Branch, Special Projects Office.

The Task Group was welcomed to LMSD, Sunnyvale by C. C. Pearson, Assistant Manager, POLARIS Missile System.

The meeting was primarily directed toward a review of the PERT system in operation at FBM contractors, with particular emphasis being given to their broader and more comprehensive application of the technique to carrying out their respective FBM program responsibilities. In addition, following the contractor presentations, the attendees were organized into three working groups to develop recommendations for SP implementation concerning the further extension and refinement of the PERT technique. A summary of the recommendations prepared by each working group and SP action or comments thereon are contained in the minutes of the proceedings.

THIRD PERT COORDINATION TASK GROUP MEETING
16 and 17 August 1960

Opening Remarks
Captain K. M. Tebo, SP-12

After expressing appreciation to LMSD for the excellent arrangements and hospitality, Captain Tebo outlined the purpose of the meeting as follows:

1. Discuss and recommend improvements that can be or have been made in the PERT system.
2. Discuss and clarify unclear PERT philosophy or procedures.
3. Pool management brainpower to obtain FBM program benefits.
4. Recognize what PERT can do and cannot do. Exploit full potential of the system.

The status of operation of the PERT system can be expressed in the following terms:

1. PERT's usefulness as a management tool for equipment and program research and development has been established. Specific examples of PERT's usefulness were cited for planning, communications, coordination and defining areas for management attention so as to prevent slippages downstream.
2. The application of PERT to prototype production was also discussed as being very useful. Prototype production was qualified as small lot (2 - 20) production on complex equipments such as SINS or Fire Control wherein firm production activity times are not yet experienced. The modus operandi here was to establish a detailed network for the first prototype and then to summarize follow-up prototypes (or equipments). If problems arise in the follow-on prototypes, the detailed network could then be applied for analysis purposes and to follow progress.
3. In true production wherein the unknowns are negligible and good experience has been gained, the line of balance method was indicated as the best method to follow progress. There is a need, however, to expand the LOB procedures in order to provide a prognostication of expected completions. This applies particularly in the gray areas when prototype production has been started but true production has not been reached, i.e., when time to complete all production activities on each item comprising the equipment is not constant. For mass production of hundreds or thousands of items such as 8" shells, application of the PERT system is unrealistic.

The amount of interest in the PERT system has grown in leaps and bounds during the past six months. PERT is being applied in such programs as Douglas Co's SKYBOLT, Western Electric's NIKE ZEUS, and Boeing Co's DYNASOAR and MOBILE MINUTEMAN. In addition, it is being considered actively for such programs as MARTIN Co's TITAN II and Bendix Co's EAGLE plus others of equal defense significance. It has been said that the Deputy Chief of Staff of the Air Force for Research and Development has requested application of PERT (another code name is PEP) to major Air Force R & D programs. Many companies are applying PERT for their research and development projects.

SP conducts bi-weekly (on Wednesdays) management briefings on the management techniques used in the POLARIS program. PERT, of course, is covered by a big portion of this briefing. There have been recently 50 to 100 persons attending these meetings.

Hundreds of requests for hand-out material on the the Polaris management techniques have been handled.

Many programs for the 704 computer have been distributed to contractors both in and out of the FBM program.

Programs for the 709, 7090 and Univac II computers will be available for distribution in the month of September.

Specific items which SP is working on with regard to PERT improvements and extensions are:

1. Improve speed of transmission of PERT data between SP, NWL Dahlgren and contractors.
2. Issue a PERT manual which will describe the procedures, practices and experiences of PERT in the FBM program. This should be published about 15 October.

3. Issue a movie describing the theory of PERT. This should be available for distribution starting about the first week in September.

4. Develop, coordinate and commence evaluation using an overall FBM Program integrated network.

5. Design a model for incorporating the COST factor compatibly and practically in the PERT format. This will enable evaluation of cost and time trade offs. A request for proposal will be sent out of SP in about a week (it was on 24 August 1960).

6. Continue to advance good management among the FBM Navy/contractor team.

7. Determine whether SP should establish decentralized computer centers on the East and West coasts.

Capt Tebo concluded his remarks by requesting that the meeting be held on a very informal basis. He would like particularly to find out wherein the Special Projects office could further help the overall effort of the contractors as far as management procedures were concerned.

FBM INTEGRATED NETWORK

Capt. K. M. Tebo
Special Projects Office

Capt. Tebo presented the Special Projects Office thinking on the overall FBM integrated network. The networks would be based on each submarine, there being, for all practical purposes, no constraints existing between the successive submarines. The integrated FBM evaluation would thus be the summary of the evaluations of the progress of each submarine. The main items to be covered in the network for each submarine were shown on Figure 1 and comprised such key objectives as delivery of the various equipments for the weapon system to the shipyard, construction of the ship, delivery of key government furnished equipment (less SP furnished) to the shipyard, delivery of missile components to NWA, delivery of logistic support items to the ship, weapon system installation test program, and ready for sea and deployment dates for the submarine.

Part of the overall FBM network would be obtained from merging the computer runs of certain existing networks. Merge points or events would have to be the same on the two or more networks to be integrated. In cases where key information for the integrated network for each ship is not now currently reported or covered by the PERT system, the contractors or naval activities responsible for the work will be requested to submit the broad information required in PERT format.

The integrated FBM network should not be confused with the integrated networks required of two or more contractors working in one area: that is to say, for example, that LMSD should coordinate with Westinghouse and General Electric to obtain an integrated missile network with respect to launching and guidance unit compatibility with the missile. The resultant integrated missile network would then become a part of the higher level FBM integrated network for each submarine. Westinghouse and General Electric would respectively furnish launching and five control equipment delivery information regarding their shipyard delivery dates. This, of course, would be in PERT format.

The integrated FBM network would thus be "hardware" oriented, since the main objective of the FBM program is to send submarines to sea fully ready to act as deterrent forces. There will be some research and development events appearing on the networks, especially for "first of a class" submarines or for submarine networks which include delivery of the first prototype of an equipment.

Within a few weeks SP will be sending to prime contractors for their specific comments a somewhat more detailed FBM integrated network than presented in Figure 1.

SPERRY ORGANIZATION FOR PERT

K. Williams
Sperry Gyroscope Company

Sperry Gyroscope is contractually responsible for the System Management of the Navigation Sub System for the 608 Class Boat.

The method used by Management is PERT at the system level. Supplementary support of the systems PERT is provided by NAVEXOS 4153 Progress Report, NAVEXOS 3856 Line of Balance and equipment PERT charts.

The preparation of the Navigation System 608 Class PERT Chart, complete with definitization of events, activities and time estimates for the activities including the Programming of the Sperry Rand Computer Univac II required two months.

To implement the PERT System an organization was required.

We have an organization chart on a viewgraph (Figure 2) and will refer to it as we give a general presentation of what the respective organizations contribute to the PERT effort.

The administrative organization is Management. The scope of the management organization will be the subject of our Mr. Goff's talk.

Supporting the management organization are the three organizations: Systems Engineering, Product Programming and Data Processing.

Systems Engineering is supported by Equipment Engineering. Product Programming is supported by the Sub-Contractors and Sperry Equipment Manufacturing. Data Processing is supported by Univac II.

The responsibility of the various organizations and their interrelationship is as follows.

Let us commence with Equipment Engineering. The Equipment Engineering people have the responsibility to Systems Engineering for the equipment design and feasibility of manufacturing of said designs; compatible of course, with Systems Engineering requirements.

Systems Engineering has the responsibility for system's level design and its attendant manufactur-

ability. The Systems Engineering, accordingly, integrates the equipment Engineering units into a complete system.

The sub contractors manufacture equipment based on Equipment Engineering designs. The sub contractor is responsible to Product Programming for the specifics of his product's progress.

System's Engineering personnel visit the sub contractors on a routine engineering basis. Product Programming and Purchasing make periodic visits to review general program progress. Product Programming implements special in plant sub contractor reviews of progress where there appears to be a need for a more complete evaluation of a given program's status, which would include the dollar expenditure rate.

The Equipment Manufacturer (Sperry), manufacture's equipment based on Equipment Engineering designs and are responsible to Product Programming for product progress.

Product Programming supported by Systems Engineering has the responsibility for the establishment of the scope and report requirements. They are also responsible for the monitoring of said scope and requirements including the evaluation of the specifics of progress of the sub contractors and equipment manufactured by Sperry.

Product Programming in conjunction with System's Engineering generates the PERT charts.

Product Programming incorporates the equipment and System's Engineering PERT inputs with the production inputs into the bi-weekly PERT report sheets. The reports are forwarded to the Computer center for Data Processing.

Data Processing is responsible to Product Programming for the necessary computer processing of the PERT bi-weekly reports.

The Computer used by Data Processing for the PERT system is a Univac II. A Univac II has the following general capabilities:

1. Memory storage capacity of 2000 words.
2. The servo console tape speed is 100 inches per second.
3. The tape density (information stored on tape) is 250 pulses per inch.
4. A built in duplicating circuitry to insure the validity of the Computer operation. (Each and every run the Computer makes is automatically and simultaneously duplicated and cross checked).
5. 90 column cards are utilized by the Univac II Computer.

An outline of how the PERT computer processing is accomplished is:

a. Data Processing initiates the Computer PERT operation with receipt of the PERT input report from Product Programming. The input information is transposed to 90 column cards.

b. After key punch, verification and card count, the cards are sent to the Computer center for report production.

c. Card to tape conversion is the first step at the Computer Center.

d. Eleven Computer runs follow cazd to tape conversion.

Run #1 is a series of validity checks of input data, and the calculation of little t_e and variance. The three time estimates are checked to assure the relationships, i.e. "optimistic" time equal to or less than the "pessimistic" time, etc. Dates are checked to be certain that the month is a number between 1 and 12, the day is between 1 and 31, etc.

Run #2 is the sorting of input data. Activities are sorted for event order.

Run #3 updates the master file.

Run #4 edits the master file. (Information is arranged for master file printout.)

Run #5 is the calculation run for T_E, T_L, and variance.

Run #6 is the calculation run for standard deviation, probability, and slack of T_E and T_L.

Run #7 subjects the incremental nomenclature input to a sequence check.

Run #8 is a nomenclature updating run of the master file.

Run #9 is the high speed printer edit and dispersion run. (Event sequence information is arranged for printout. Subsequent run is edited.)

Run #10 high speed printer edit and sort. (Slack and date sequences are arranged for printout.)

Run #11 is the graphic presentation run, (computer printout).

Any and all discrepancies between incremental input data and the master file are typed on the computer console printer. A copy of the console printout is delivered with the final reports, (computer printouts) for analytical and corrective action.

System's Engineering and Product Programming effect a written analysis, bi-weekly, of the "state of health" of the program. The report is forwarded to management with computer printouts for management action and transmittal to Special Projects.

We have touched on the generalities of the Sperry PERT organization and it's operation.

In conclusion, Sperry is evaluating the expansion of the PERT system to include manpower and $ accountability with the use of a "Special Management Analytical Report Technique". We look forward six months with the anticipation of having made substantial progress in this area.

We have contained our comments appreciating the agenda. However, if there are any questions we will make every effort to answer them.

OPTIMUM UTILIZATION OF PERT DATA

D. Goff
Sperry Gyroscope Company

Gentlemen, Mr. Williams has presented to you an accurate and informative analysis of the techniques employed by Sperry in processing PERT data on the FBM Navigation Subsystem. Therefore, our next pertinent point for consideration is the optimum utilization of this data.

Progress on PERT to date could have proceeded faster were it not such an advanced concept in weapon system management. It is true that PERT is an

established system of self inspection (and customer inspection) not known heretofore. Therefore, the concept of PERT must be sold. The basic premise of PERT could be stated as follows:

"Early, persistent and continuous self inspection by an organization makes possible objective analyses of system troubles at early stages in the program, thus saving money and minimizing schedule delays."

This concept is being sold to every contributing member within the Sperry Marine Division. PERT is also attracting increasing attention throughout our entire company. The results to date have been:

1. Faster reporting due to increased interest.
2. More accurate reporting due to increased contribution and review.
3. More objective reporting.

There are four keystones to optimum utilization of PERT. The first three, just presented are:

1. Speed
2. Accuracy
3. Objectivity

The fourth keystone is dependent upon people outside of the PERT organization. It is essential that PERT have the full hearted support of:

1. All levels of company management concerned with the particular program.
2. Cognizant customer personnel.

The first three keystones are accomplished by hard work and selling of the PERT concept. The fourth keystone is accomplished by proving that the PERT data is up-to-date and correct.

It is time now to present the PERT Equipment Status Chart which is the progress date bible for the FBM Navigation Subsystem: (Chart omitted due to security classification)

Discussion of chart –

1. Serial number
2. Three dates
3. Equipment allocation
4. Distribution and reduction
5. Analysis
6. Management Center

This chart is being utilized forceably on our program. In addition to Sperry Management support we are receiving extremely energetic support from Captain Tebo and SP-12, Lt. Veccia and SP-24, and Mr. Cariski and our local SPOTR organization. The dominant philosophy today is that if a person has information different from PERT, that person is wrong for not having put the information into the PERT system.

With this customer support and Sperry support, optimum utilization of Pert data is being made by making this data the basis of system decisions in all matters affected by equipment status.

What does the future hold for PERT within SPERRY?

1. Faster, more accurate information.
2. More universal support of the program.
3. Expanded usage of PERT data in Management planning and control.

REALISTIC SCHEDULING THROUGH PERT

H. S. Phelps
Aerojet-General Corporation

I. INTRODUCTION

Schedules have been with us from time of the first supplier and his customer. Some have been met, more have not. (I've missed my share since entering the missile (rocket) business in 1947 at White Sands Proving Grounds.) Most of the time we don't know enough facts upon which to base a schedule or even a guess as to when something will be finished. A little two-man garage can't always hit a schedule for there are many little items that throw them. Add the thousands of people required to perform a mission as great as the FBMS and your schedule problems grow like topsy.

Our problem is two-fold. We must determine first if an end schedule is realistic; and secondly, set, by some logical means, the intermediate schedule realistically so that they have a fair chance of being attained.

Intermediate milepost schedules are important. They generate targets or goals to be attained and are essential in the communications between people doing work, suppliers, project management, top management, and the customer.

II. SCHEDULING TECHNIQUE DEVELOPMENT

If we are to put faith in our PERT system for management control, then we should use it as a scheduling tool. This is undoubtedly being done to some extent by most users. We at Aerojet-General have taken some positive steps toward this end. The methodology and techniques required to building realistic schedules through the use of the system and the computer have been developed through a three-phase program.

A. PHASE I - Factors Affecting Schedule Establishment and Attainment.

Establishing a good schedule and subsequent attainment of that schedule requires the following:

1. Constant evaluation of progress toward a scheduled objective.
2. Good definition of activities leading to scheduled events.
3. Good awareness of the effect on other portions of the total task if a scheduled date is not met.
4. Adequate frequency of scheduled events.
5. Person who must meet the schedule should feel he has helped to establish it.
6. Positive management direction.

The PERT system with a properly planned network fulfills the first four of these considerations. We have an efficient means of evaluation progress—work being done by people on tasks and sub-tasks as the program develops. We have provided the people on the line with a clear concise picture of the tasks required while at the same time providing

management with a tool for managing. We employ probably the most effective means of portraying the net effect of a slipped schedule on the events which follow. The frequency of scheduled events can be directly controlled in the network development.

We have thus through the PERT system, corrected four usually negative factors in schedule achievement.

The next factor, Item 5, involves a human variable which revolves around the psychological behavior of individuals operating within a group. If we achieve the first four objectives, we have a human group reaction with a negative feeling toward schedules. In breaking this group reaction down to the individual level, there seems to be a psychological reaction which builds a block against acceptance or conformance. Some contributing factors to this reaction are (1) a feeling that the individuals and/or groups were not a part of establishing the goal, and (2) a feeling that people up the line have a somewhat low regard for the edicted schedule. There are many other conditions and variables which contribute to a reaction of this nature. A great amount of research work has been done in industrial psychology and human factors field dealing with these problems, much of which your are familiar with.

A group must have targets to aim for so that they can as individuals and collectively as a group conceive and evaluate their relative position. This evaluation, however, it is a real thing even though somewhat intangible.

The last factor referred to above—positive management direction—is of course recognized as essential by all supervisory personnel. However, this is not easily achieved. Supervisors and managers at all levels are affected by the factors mentioned here in their respective groups.

We have said that the first four factors are controllable through PERT type systems but what about the last two? How can we make the people in the group feel they are a part of a schedule and at the same time provide a realistic target for them? We have the answer in our system. We can generate a realistic schedule at close intervals based on the time estimates the very people we are talking about gave us. Positive management direction will result. Supervisors now have a means of relating their position relative to others in the total task. They have a realistic incentive for their group which now becomes a team.

B. PHASE II - Approach to Using PERT for Establishing Schedules.

The second phase of our effort was directed toward defining the approach to the problem. Whatever method was developed, there were two prime requirements. First, it must be practical or we could not expect to get any results regardless of how good it was. Secondly, the schedule so generated must be capable of being accepted as the only schedule.

After taking a critical look at our own system, we found that more emphasis should be placed on planning. I am sure that everyone who has had experience with PERT will agree that planning is not only a requirement—it is often a result. We would like to make several points in the planning area which we feel are of prime importance and trust that you will not find them too redundant.

1. Scope of Planning. The definition of the total task represents the key to the development of a plan of doing business. This might be considered the meat of a proposal along with the composite thinking of the Project Manager and his key personnel. In practice, it is difficult to collect this information on a piecemeal basis talking to first one person and then another while at the same time sifting documents for significant facts relative to the total task. If, in fact, one is able to put together a plan, it may be arbitrary in nature and not very realistic.

How can we get around this first major hurdle? One very effective approach is through the use of *small* conferences in an atmosphere of complete devotion to the problem at hand. (This too may be somewhat unrealistic.) However, in *small groups* of PERT planning personnel and top project technical brains, a skeleton network comprised of unscheduled major events and milestones can be developed quite successfully. This is accomplished by taking successively the major areas of effort required to fulfill the task objectives, defining the starting and completing events and establishing their respective dates. Major areas of constraint and interdependencies are determined, thus defining the limited network developed at the "brain picking" session as well as establishing a criterion for the more detailed plan which follows.

Now that we are armed with a clear concise picture of all the major activities and events which comprise the project we can progress to the next major step in the PERT planning process.

2. Level of Detail. How much detail is really needed to effectively manage a project through PERT type techniques? This is probably one of the most widely discussed and most controversial areas in the system. We like to compare it to an old quality control hypothesis that "the level of quality control and inspection should be in direct relation to the product's cost and market." Thus one should pay more attention to detailing areas which have the greatest program delay potential. These areas should be detailed to a higher level than those having a lesser impact potential on the overall program.

The most desirable minimum level of detail appears to be that which reaches the direct responsibility of first line supervisor. This should provide time estimates which are not schedule contaminated.

3. Sequencing of Events. The last point we would like to make in the area of planning as a prerequisite to realistic scheduling deals with logical sequencing.

We have currently two concepts at numbering a network (flow chart) in PERT today. One is the use of a random assignment of numbers to events.

These numbers sometimes have an event meaning or relationship to some sub-system or component. The network data is then pumped into a computer which either accepts them at face value or goes through a routine of sorting and re-assigning numbers for computation purposes, with the output reverting to the original input numbers.

The other approach is the one we use at Aerojet-General. It is based on the requirement that a successor event number cannot be less than its predecessor. Thus, all numbers start from a single event at the beginning of a program and ascend numerically to a single end event.

There are two fundamental reasons for this. The first and most important is that we feel the ascending number requirement helps people plan a little better—a little more logically. Through placing this requirement on the people developing networks, there is a tendency to organize their thinking in an orderly manner—to periodically raise the question as to which event really comes first.

The second reason for using the ascending numbering system is purely a mechanical one—enabling us to shorten our computing time.

Through the use of logic, conceptual model building, and ascending numbering, a realistic portrayal of a project can be depicted. Now that we have accomplished this portion of the PERT system requirement, we have probably derived sixty per cent (60%) of the system's benefit—planning!

C. PHASE III - Computer Technique

With the project planning, estimating, and input data prepared, we can compute our capability of meeting the one end schedule. Should the analysis indicate that the planned approach is not compatible with the desired customer schedule, then the plan and time estimates should be re-evaluated. When the plan is deemed correct, the end schedule should have been met. In cases where it is impossible to conceive a logical plan which will meet the schedule, relief should be negotiated.

A conceptual model was developed with the frame of reference being drawn around the scope of operation involved at the Solid Rocket Plant, existing computer program, desired results, previously mentioned factors and the time available to accomplish the task.

Early in the effort, it became evident that the technique should be related to probability. Further investigation did not change this assumption. Several sophisticated approaches were evaluated such as placing weighing factors on certain activities which would allow the computer to adjust the mean t_e (weighted average of three time estimates) and establish new preceeding and succeeding event connections within a pre-established criterion. This approach became much too involved for immediate consideration. It has good potential even though it is not practical at this time. It will be explored more fully at a later date along with some analog adventures under consideration. It was further decided that time latest (T_L) should not be used as a criterion since it becomes extremely misleading in long R&D programs.

Our approach is based on these assumptions: (1) Project Management and/or Top Management have a feeling as to the minimum probability they are willing to accept on schedules for a given project. (2) The PERT network for any given program is sound and representative of the tasks required.

The input to the computer is the normal PERT data input with the addition of the probability factor desired for all schedules in the program. The acceptable range may vary widely above or below the .50 level. The technique is as follows:

1. A probability curve is developed for each event in the normal manner, which takes the longest series of activities leading to the event. Calculate the accumulated variance for the event and then develop a standard curve. (See Figure 3)
2. The predicted date P_t is equal to .5 on the probability curve above. This point is fixed.
3. We then move up the time baseline till we reach a point which corresponds to the probability factor called for on the input.
4. The time difference $_dx_t$ between the predicted time P_t and the new schedule point st_t is added to P_t which gives us the desired schedule time; $T_{s_t} = P_t + {}_dx_t$. The T_{s_t} is now converted into a calendar date through the normal program calendar.
5. The new schedule time is now written on an output tape along with the event numbers. This tape is then placed on a tape to card unit and through the use of other peripheral equipment, the new dates are punched into the data deck.

III. SUMMARY

This method of scheduling or re-scheduling an entire program is for the most part a direct result of people on the job providing time estimates to the PERT program planners. This data then reflects what people on the job say they expect to do. We are really telling them they must complete the job before a certain schedule date because they said they could.

The project manager and all his people down the line know what activities they must complete before they can call the job (event) complete. Their target dates are frequent enough so that they do not lose sight of the next scheduled event.

The people in the group have a unity about their objectives because they are a part of the team—they must meet the schedule. Group and personal ego tells them they must meet the schedule. Management has positive direction because they know what must be done and when it must be finished.

IV. CONCLUSIONS

A. With the incorporation of the realistic schedule system, we have at our disposal a tool which when properly used, will take the guesswork out of setting schedules and provide many other internal schedules not available.

B. This system will eliminate the problem of too many schedules. There should be only *one schedule*—that generated or checked by the system. I cannot over-emphasize the importance of having one schedule.

C. While this method is not the ultimate, we can set schedules and evaluate them while we develop a more sophisticated method.

THE UTILITY OF PERT IN PRODUCTION EVALUATION AND CONTROL

Russell D. Archibald
Aeroiet-General Corporation

I. DEVELOPMENT OF A SOLID ROCKET MOTOR PRODUCTION PERT PROGRAM AT AGC.

Concurrent with the transition of a current POLARIS Program from R&D into production, the related PERT Program went through a similar change. This presentation is intended to explain how a PERT Program was developed for the production phase, evaluate the benefits and limitations of that program, and present some conclusions with regard to the utility of PERT in production evaluation and control.

A. NETWORK DEVELOPMENT. As design events were completed in the subject program, the standard PERT network became less and less useful. After several trials, a repetitive motor processing loop network was evolved which in essence is nothing more than the manufacturing sequence assembly chart. The runs to date have included only six events and five activities and have centered on the chanber components. The computer program is established to compute for each motor all remaining activities and events from either the scheduled or actual receipt of chamber or from the last completed event in the loop.

B. TIME ESTIMATES. Brief studies were made of past motor processing performance data and for each activity contained in the PERT Motor Loop, a set of three time estimates was established. By plotting the actual time intervals for a number of units in a given activity, it became apparent that most of these fell within a well-defined envelope. The optimistic time for each activity was taken as the best time ever achieved on any unit, the pessimistic time was taken as the worst achieved after discarding a very few cases that were obviously outside the envelope, and the most likely time was established by arithmetic average of all units.

C. REPORT GENERATION AND UP-DATING TECHNIQUES. Input data is given to the computer in the format shown in Figure 4. The output data consists of information relating to every activity in accordance with the standard AGC IBM 704 Program. It was found that the bulk of this output was excessive and a card output routine was added for the end event relating to each motor. These cards are then sorted in proper chronological or assignment sequence and printed in the format shown in Figure 5. To provide a better overall picture, the last completed PERT event and related date is manually entered in the columns shown. Up-dating is accomplished by manual changes on an input card listing which are punched directly into new cards. These cards are collated into the input deck and the revised program is then ready to run. To further improve the usefulness of the output, a graphic presentation was developed as shown in Figure 6. The sample outputs have been doctored in order to declassify them, and do not reflect any particular program.

II. EVALUATION OF THE AGC PRODUCTION TYPE PERT PROGRAM

A. BENEFITS. The primary benefits derived to date from this phase of the AGC PERT effort relate to an independent evaluation of the production control system. The results cannot be used to predict delivery of any given motor with any accuracy due to spread in time spans and the nature of the probability approach, but they do present an accurate picture of overall trends. One measure of the accuracy of the PERT predictions is the comparison of the total number of units predicted to be delivered with the total number actually delivered in a given time period. This ratio has varied as shown below.

Reporting Period	*Ratio of Predicted to Actual Units Delivered*
April	1.86
May	1.90
June	1.30
July	0.90

The initial predictions seem to be rather optimistic but the latest prediction is approaching the optimum ratio. It is believed that PERT in this situation should be slightly on the pessimistic side. The initial optimism is probably due to poorer than average performance for the group of motors in question, primarily because of priority conflicts with other programs. Minor revisions to the span times were made during this period, but these were not sufficiently large to cause the significant changes shown.

B. LIMITS OF USEFULNESS. Efforts to expand the number of events and activities in the motor loop have resulted in excessive manpower requirements and computer time. Because of the nature of the motor process, in which the chamber plays a dominant rôle, the inclusion of other components is not of prime importance. The span times developed for the chamber actually show the effects of delays caused by other components. As pointed out above, the PERT predictions, since they are based on the .50 probability, cannot be used specifically with an acceptable degree of accuracy for production control processes. The integration of this repetitive loop for selected R&D motors into an overall PERT network (for another program) has

produced very interesting results.

III. CONCLUSIONS CONCERNING THE UTILITY OF PERT IN PRODUCTION EVALUATION AND CONTROL

From our experience in attempting to follow a given program into the production area, we found that there are limited benefits to be derived from applying PERT to this area. Figure 7 shows an overall program in a PERT network form and indicates the presently accepted areas of application of PERT. In the production run, the production control system developed for the particular type of item being manufactured not only controls the inflow of materials to the production line but also should generate evaluation reports which fulfill the primary function of PERT.

A. EVOLUTION INTO MECHANIZED PRODUCTION CONTROL SYSTEM. The natural evolution of the PERT approach into a mechanized production control system is shown in Figure 7. The uncertainty surrounding the R&D phase is replaced by relative certainty in the production phase. The PERT network evolves into a standardized Manufacturing Assembly Sequence Chart. The three time estimates narrow down to one standard manufacturing time span for each activity. The PERT reports evolve into mechanized Line of Balance reports.

B. PROGRAM REPORTS. PERT Reports to fulfill the primary functions shown in Figure 7.are most important and useful during the R&D phase, extending into initial units of production. Line of Balance or similar reports, on the other hand, are not suited to this area due to the uncertainties involved and the continual re-planning and re-scheduling needed in an R&D effort. Line of Balance reports are extremely useful, however, in the production situation. It appears that the best utilization of program evaluation manpower would result in phasing out the PERT effort after delivery of the first few production units, and limiting the Line of Balance effort to the production situation. The smooth transition from PERT to Production Control requires that each must be compatible with the other, and for maximum efficiency each must utilize common mechanized data processing techniques and information sources.

USE OF PERT AT MARE ISLAND

T. R. Walsh
Mare Island Naval Shipyard

Mare Island Naval Shipyard is a relative newcomer to PERT methodology, our introduction, in Mid-March by Captain Tebo and the SP—BUSHIPS team, to this technique, resulted in preparation of a network covering the FBM portion of the THEODORE ROOSEVELT, SSBN 600, currently under construction at the Shipyard. Interdepartmental responsibilities were established one week later. By Mid-April we had taken a better look at our initial networks, reviewed them with Production Shop Representatives, the Weapons System Test Group Engineers and Technicians, Progress and Scheduling Section Representatives, made appropriate revisions, and resubmitted a revised network.

Continued maintenance of PERT networks and submission of reports is accomplished by the Central Scheduling Section with input on the status of equipment delivery and work progress furnished by the progressman. Information relative to test revision, sequences and time estimates are provided by the Weapons System Test Group.

The Scheduling Section on the Shipyard is a part of the Production Engineering Division, a major division of the Production Department, and is responsible for the preparation of all work schedules which require time coordination of more than one department or activity.

Firm schedules developed by Central Scheduling must have the concurrence of the Shipbuilding Superintendent prior to issuance to Production Shops.

The Progress Section is a part of the Shipbuilding Division. Individual progressmen, similar to expediters in Industry, report directly to the Ship Superintendent.

PERT networks are revised as necessary, posted for current status, and reissued monthly to interested Shipyard departments as indicated on Figure 8. NORC computer runs (including Graphic Report - 1 Year form) are also routed to interested Shipyard departments for their information and guidance.

We have, on our network, (Figure 9) features which we find advantageous to us. We indicate, above each event, a scheduled completion date. By use of a thermometer indicator on the event we indicate the current status of the activity controlling the event, and when completed the actual date is inserted below the event. This we fell is particularly valuable for historical records. We show, by a colored line, the most critical path as indicated by NORC. By use of a "terminal Block" in individual networks we tie in preceding or following events from other networks in such a manner that any one network will contain all necessary reference information. Posting of our networks in this manner we feel provides, at a glance, general status and directs attention to the critical path.

Advantages of Shipyard use of PERT are I think rather straight forward, in that it is a plan for planning, for continuous program status and finally for evaluation.

PERT FORCES ADVANCE PLANNING

1. You must identify all significant individual activities or events necessary to complete the project successfully.
2. You must determine the necessary interdependencies between these events and discover the optimum or available sequence for their accomplishment.
3. PERT forces improved estimating for time coordination by requiring three estimates reflecting

any uncertain conditions existing at the time of estimate.

4. PERT forces early involvement of production and technical personnel with the total project in the review of events, sequences, and time estimates.

WORK PROCESS

1. Provides a consistent basis for communication.
2. Your current position relative to the entire task is readily discernible through graphic presentation.
3. Provides progress evaluation.
4. Actual or potential slippages are discovered or uncovered early.
5. Rapid evaluation of the effect deviations from plan may generate.
6. Provides a method for establishing a revised plan of action as may be required.

Local application of PERT has been on a rather minimal basis with assignment of personnel within my organization on a part (Not PERT) time basis, actually Mr. Van Dolson is the group.

It is the reporting media to SP. Its methodical approach has been an aid to the Weapons System Test Group for local detailed planning. We have found the PERT networks and computer output useful tools in the development and maintenance of FBM weapons system schedules. Those concerned have been surprised by the close agreement of PERT expected dates with our actual experience of completions.

One of the basic intents of PERT is to provide predictions of probable accomplishment of work and as a result provide a basis for changes in local planning and scheduling. Our experience to date however has indicated that the delays encountered have almost exclusively been as a result of late or changed delivery of contractor furnished equipment. We have rescheduled as a result of this intelligence but generally this has not provided any basis for local management action, since no alternative courses are available. Critical paths reported to us from NORC only confirm that which was readily pre-determined because of the late component deliveries.

Our job is to time coordinate the effort of the Shipyard to build in an orderly, timely, and economical manner the complete SSBN submarine. To this end several separate though interdependent groups are involved. (Figure 10)

PERT currently is applied to the FBM portion of the THEODORE ROOSEVELT only. Should this portion of the vessel be controlling the advantages of program utilization by management are apparent. However should another area be controlling for completion other methods are utilized for this analysis and projection.

Potential of PERT for Shipyard application is not, at this time, fully utilized. Capability of integration with other necessary Shipyard programs appears to be possible and would be necessary for a total management evaluation of overall project.

USE OF PERT AT NEWPORT NEWS

C. S. Turner, Jr.
Newport News Shipbuilding Corp.

Gentlemen, I am happy to be here with you, the people who have made the PERT concept work. We recognize that PERT is doing a job for you, otherwise the idea would not have lived. PERT is also doing a good job for us. In retrospect, it would have been more advantageous if Sp 12 had brought the PERT "Road Show" to Newport News earlier in our FBM program.

Newport News entered the Polaris Submarine program July 30, 1958 when we awarded the contract for the USS ROBERT E. LEE, SSB(N) 601. We have successfully conducted test programs in Aircraft Carrier construction, but we soon realized that in the POLARIS program we were embarked on a test program more concentrated and confusing than we had ever seen. Information, printed, verbal and rumored poured in. This information was in the form of TRO's, Test Indexes, Test Forms and occasional visits from contractors already well into the test program. Our problem was—How do you organize all this information so it could be presented to the various shipyard trades anxious to prepare their work?

Our first efforts to lay out the test program was the bar chart. Question—How long does it take to perform a test? Question—What sequence must the test follow? Question—What construction must be completed before a test can be performed or vice versa? What test can be run when a certain amount of construction has been completed? We made our bar charts. We believe they were good bar charts and they got our program started. But things change as I am sure everyone of you realizes. Equipment delivery dates, test requirements, construction time, Design—all these things necessarily changed. This would start a whole new chain of questions and answers and analysis all leading to a new bar chart. This became an almost continuous process and eventually created resentment and lack of faith in the schedule. Our first line supervisors wanted an up to date schedule. They were looking for the latest information available from any source experienced in installation and testing of equipment they had never seen. Bar charts were not the answer. We still have bar charts, and use them, but the PERT reports are now looked to as the latest, most up to date test program outline.

Before Newport News was introduced to PERT, the Bureau of Weapons representative at the Supervisor of Shipbuilding Office suggested that the Shipyard draw up a "Tree of Knowledge" for the test program. This suggestion was well received but our attempts to do this bogged down in a sea of unanswered questions. This failure pointed out how badly such a presentation was needed.

When Sp 12 came to Newport News, our test program was in the construction and Phase I and II testing stages. Many items of equipment had not been received and the delivery dates promised for some components were several months in the future.

Our program was moving well and with direction, but planning was difficult and a major problem.

We were directed to install the PERT System and to have our networks and time estimates ready to make our input in three days. This task fell to our Weapons System Test Group, and it was no easy task. I am sure that most members of the Test Group felt as I did in the beginning—skeptical. But as we worked, with Sp 12 assisting, one problem after another was met and solved and our doubts turned into enthusiasm. We began to realize that PERT could help us with many problems that had been with us from the beginning. PERT has helped us and our enthusiasm continues.

When our yard supervision was approached with this new concept, there was almost immediate acceptance followed by a flood of suggestions on its use. The Test Group was glad to receive these suggestions and used them whenever possible. We wanted everyone in the FBM program to participate and to become a member of the PERT team. We needed the support of everyone from mechanics to top supervision if we were going to get the most out of PERT.

Our approach to PERT is what we refer to as the unsophisticated approach. We try to stay away from the mathematics involved, the computer used and theory. Our sales talk tries to convince listeners that PERT is nothing particularly new but is what anyone planning his work has been doing in his head. We try to lay out our network charts as simply as possible and to assign easily understood titles to the activities. We do not want anyone to shy away from PERT. We want our first line supervision to use PERT, not to feel that PERT is another bothersome report to make every two weeks. These people are the chief source of information going into the bi-weekly reports. I think it is to PERT's credit that these supervisors are as interested as anyone in the yard to see what the next PERT report will predict.

We have drawn four network charts which include all activities and events from March 21st this year—the initial PERT report date—until completion of the test program. About 180 events are listed. These events are material deliveries, construction and testing items. These charts were distributed to members of the Weapons System Test Group and one set is posted in an information center located on the pier adjacent to the submarine. This center is used by the Test Group for daily planning meetings and the charts are frequently referred to. As activities required to complete an event are begun, a diagonal is drawn, in red, thru the activity title block. When an event is completed an X is drawn thru the title block and the completion date is entered. Although no attempt was made to align the events on a time scale, all paths flow from left to right and it is readily apparent which paths are getting behind. Changes to the network charts are marked by each member changing his own copy We avoid re-issues, when possible, to keep paperwork at a minimum. We have also found that members of the test group make notes on their individual copies which would have to be transcribed to new charts after each issue. This was one problem we encountered with bar charts.

In the construction of the weapons areas, equipment comes from many sources—material purchased from other concerns, Government Furnished Equipment, Shipyard Manufactured Material, Shipyard Stock Items, Test Fixtures, etc. Sometimes it becomes difficult to keep track of this material, particularly in cases when it becomes available over an extended time interval. By making receipt of material an event and marking the event complete, we keep the material status conveniently posted.

Testing follows construction. We have grouped our tests into 124 events. We think that graphically presenting the interdependencies between tests, as is done on the network charts, is very helpful. Here is the "Tree of Knowledge" we had been looking for. We have not found a better way to keep our thinking straight. And certainly, these charts are very persuasive when the complexity of the test program needs to be pointed out.

PERT reports are used as our Weapon System Test Schedule. The technicians, from whom time estimates are gathered, have told me this—they are not always familiar with equipment with which they will be working, but by making time estimates for each step along a path, they will arrive at the best estimate possible for the end date. Another advantage to scheduling with PERT is the speed with which faulty thinking is brought to light. This is especially valuable when the mistake is toward the end of the program and could possibly be overlooked until then. When questionable expected dates turn up, we review the path immediately looking for incorrect prerequisites and/or time estimates. I might add that for the first few weeks we questioned the accuracy of the computer, be we soon learned that any mistakes were ours. We are of course interested in the slack sort to point out our greatest problem areas. Whenever possible, the paths with negative slack are given top priority on the work list. In several instances, emphasis given critical paths has resulted in bettering our time estimates.

We use PERT reports to update our bar charts. We lay out a time interval from the date the chart is drawn to the computed end of work date on graph paper. Incomplete activities are drawn as bars, located by the expected completion dates as listed in the report. Next, a time interval from the date of the chart to scheduled RFS is drawn. This scale is the same length as the first time scale, but in our case, represents a different time interval. The bars are then projected to the second scale which then gives us schedule dates for each event required to meet the scheduled completion date. This is a quick way to draw a bar chart since prerequisites and sequence are already factored into the expected time sort.

Our schedule must be flexible. We have encountered many equipment date changes, changes adding tests, changes deleting test and changes we

have made ourselves to the test program. We must know when we can expect to perform major events such as those involving sea trials. We must know when we need test equipment. As we beat our schedule or fall behind PERT evaluates the change and keeps us informed. Frequently the shipyard is requested to give the latest acceptable delivery dates for equipment. We now have only to refer to the latest allowable date column for an answer. Being able to change the time estimate for a single activity and having PERT tell us what has happened to each following event all the way through to ready for sea has certainly saved us time and clerical effort.

PERT reports keep work from being over-looked. The requirement for bi-weekly issue forces review of at least part of the test program every two weeks. This helps keep the program orderly.

Each subsystem must be tested with the other subsystems during Phase V and VI testing. We have worked out the following method to schedule Phase V and VI testing. From information furnished by Vitro, the Phase V and VI tests were drawn on a PERT network chart. Only the interdependencies between these Phase V and VI tests were considered up until this time. Then each Vitro test was investigated to see which subsystem tests, if any, were prerequisites. If prerequisites were involved they were listed in a title block to the left of the Phase V or VI test involved. This was a convenient place to keep a list of the prerequisite tests for reference. The block was assigned an event number and an activity line was drawn to the proper Phase V or VI test. This activity was assigned the times estimated for completion of the Vitro test. The prerequisite block is duplicated on the subsystem charts and titled "Prerequisites for Vitro Test so and so." Activity lines are drawn from any events on the chart that were listed in the prerequisite blocks. These activity lines are assigned 0, 0, 0 time estimates. Therefore, the expected date of the prerequisite block would be the same as the latest expected date of all tests listed in the block. From this date we can determine the earliest date we may expect to begin a Phase V or VI test. We may expand this idea to include all tests so that the PERT report would print out the starting and completion dates for each test.

PERT information is distributed through the Weapons System Test Group. The Test Group consists of the test coordinator as chairman, the test conductors as representatives of the waterfront trades, the FBM Project Officer from the local Supervisor of Shipbuilding Office, subsystem contractor representatives, representatives of the Ship's Force, and a planner from our Production Engineering Department. PERT reports are received by the Production Engineer for management and referred to the Production Engineering Planner for processing. The Planner sends copies of the report to the test co-ordinator and to the test conductors. The test coordinator reviews the report and discusses its contents with the Test Group at our regular meetings. The Test Conductors make time estimates. Equipment Delivery Dates, Test Status, etc. are reviewed by all members of the test group. Information which should be reported is recorded by the Production Planner and included in the bi-weekly reports. Questions from SP are referred to the Planner and PERT analysis reports are sent to the Production Engineer for review and action. The liaison between Sp 12 and the Shipyard has been excellent.

Our thinking has been influenced by PERT. More and more planning problems are being met by laying out a rough network and then making time estimates. The mechanic doing the job, the man who can help planning more than anyone, likes this method of job analysis. It gives him a chance to prove how involved his work is and to show up someone from the office divisions, like myself, who had over simplified his work. This is a suggestion made to me by an electrician—for planning test programs for future ships, start at the beginning with such events as platforms erected, foundations landed, cable pulled. Then make time estimates, based on our experience with the SSB(N) 601. The initial PERT report would then be used to develop our schedule. Bar charts or other types of schedules would be based on this first report. We would also have listed the latest allowable equipment delivery dates to compare with our promise dates. This suggestion will be tried for following ships. I wanted to tell you about this suggestion because it demonstrates that our people are really aware that PERT can help them and they are anxious to use it.

We have learned much about PERT during the past five months. We are continuing to expand the use of PERT. Future PERT set ups will be more accurate and therefore more useful to us. All things considered, PERT is doing a good job for us.

USE OF PERT FOR SUBCONTRACTOR PROGRAM COORDINATION AT MIT, GE, AND RAYTHEON

I. Halzel
MIT Instrumentation Laboratory

During the past six months we at MIT have had the satisfaction of seeing our PERT program grow in stature and acceptance and scope from a small, limited effort to a dynamic, widely accepted and respected technique of program management. We have effected an evolution of PERT networks starting initially with plans and ideas both broad and general in concept to current networks, fourteen in number, interconnected and related to reveal the most detailed plans of the Laboratory to accomplish the task at hand. This period of time has also seen the development and implementation of procedures at MIT whereby that important cycle of time to transmit data to the computer and receive print out

data back has been reduced from ten days to two days, a factor which, together with more frequent inputs, has resulted in PERT data which is practically concurrent with everyday operations. Furthermore, I do not think that we could hope for much better service than we have had in the past month where, in less than 24 hours after a TWX input has been sent by MIT, all events on the critical path are TWX'd back to MIT. In addition to obtaining greater speed of input and output data, we have improved our operating and analytic ability by devising new type print outs tailored to furnish us with data separated by systems, time and group leader—tools which have become one of our most effective means of communicating with engineers who are the source of input data to the PERT program. These print outs, called 5th and 6th digit print outs, will be discussed in more detail later on. Finally, the past six months have seen a logical extension of PERT techniques to the complex area of subcontractor program coordination where, out of the tangle and array of interconnecting and intertwining networks, we are able to enjoy and envision a degree of communication, cooperation, and coordination hitherto unheard of. We at MIT, together with our major subcontractors, General Electric and Raytheon, are in the throes of a three-way connected PERT relationship. The burden is heavy now, but based on the successful experience we have had at MIT and our initial accomplishments to date, I have every reason to believe that this experiment will result in a positive and tangible contribution to the successful delivery of advanced guidance systems to the POLARIS program.

I would like to discuss briefly the operation of our program at MIT. Our task in the Laboratory is to develop a light weight advanced guidance system. Our plans call for the development of new designs, circuits and mechanical parts for the guidance system, the development of new techniques of fabrication, such as modules of welded construction rather than conventional soldered type, and finally the assembly of prototype systems incorporating sub-assemblies which have been designed and manufactured by responsible subdivisions in the Laboratory. To supplement the efforts of the Laboratory, assistance in the form of industrial support is being obtained from General Electric and Raytheon plants.

This bar chart (Ed. Note: The chart has been omitted from the summary minutes) illustrates the fact that the prototype systems are being built in parallel, and are staggered, to be completed about one a month. It is interesting to note that these charts, which cannot reflect the many interrelationships between sub-assemblies and total systems, say in effect that all systems will be completed about three months ahead of time. But going back over the history of these bar charts and the people who contributed the input information reveals many idiosyncracies of people and their planning techniques, which PERT has a method of handling.

During the initial preparation of this bar chart, our engineers told us that the shaded bars indicate the time it would take to complete sub-assemblies for which they were responsible. Two months later the same engineers were obliged to furnish new estimates of time, shown by the cross hatched increment; in many cases, one to two months were added on. Finally, two months later, another revision was made and, in most cases, another four to twelve weeks was added on. Our official planning, scheduling, and review technique is PERT and fortunately, it has painted a clearer, more concise, and significant picture of what our detailed plans really mean in terms of meeting our objectives. At any given time, we know where we are going, how fast we are moving, when we are going to get there and, most important of all, what to do to get there sooner. Additionally, our PERT techniques of review and analysis enable us to become aware of future problems, bottlenecks, and inconsistencies well ahead of time—in our case, six to ten months, and to plan for ways and means of preventing the trouble from ultimately arising. The fact remains that the PERT technique, or "discipline" as I like to call it, its methods and procedure, and finally, the PERT network of events and activities, constitute the main stream of planning the R&D program at MIT, Instrumentation Laboratory.

The viewgraph now on the screen reveals the progress we have made in the past six months in driving our objective event closer and closer to a most important and critical schedule date. At the second PERT Coordination Task Group Meeting, Ken Dunipace pointed out that our major objective, which was 70 weeks away at that time, was going to be about 50 weeks late. This outlook was indeed disconcerting. Today, with our major objective about 50 weeks away, our PERT outlook reveals a negative slack path of about 12 weeks, and, based on a day-to-day analysis of our critical paths and the changes now under consideration, we have high hopes of reaching our objective on target date. It is obvious that a chart like this does not reflect the time and effort spent to derive this important data, and its simplicity does not do justice to the technique we call PERT. However, if we take a close look at the graph, I believe we can get a better understanding of the work involved. Six months ago our inputs were sent to the computer about twice a month. It wasn't long before we felt our inputs had to be submitted more often and as we move down this line indicating frequency of input we recognize that the time between each input has been shortened from every 15 days to about every 7 days and less.

Concurrent with our successful efforts to expedite data to and from the computer, we have requested and received from Dahlgren several new print outs which have contributed greatly towards our ability to more easily analyze the data. Two factors have made these possible; first, the method that we use to identify our events and networks provides greater flexibility in reporting with a minimum of re-programming, and second, the prompt and positive cooperation of our colleagues at Dahlgren in fulfilling

requests for a particular type of print out. I'd like to say at this time that their cooperation has never faltered, and for this we are very grateful.

With reference to our methods of coding events, we have chosen to relate the fifth and sixth digits of the nine digit code to functional entities in the Lab. In the case of the fifth digit, events related to an individual guidance system are controlled by this digit. In the case of the sixth digit we have been able to assign a control number to each of our group leaders. Even though Group Leaders' efforts are applied across the board to all of the systems, each has been assigned responsibility to a particular area of endeavor, such as design of analog circuits, design of computer circuits, design and manufacture of gimbal assemblies, etc. The last three digits allow us the possibility of 999 events for every combination of 5th and 6th digits that we make, an allowance far in excess of our needs.

Since we have conscientiously assigned code numbers within this frame of reference, I believe the possibilities for devising and tailoring print outs data to fit our needs becomes obvious. The real value, however, of our coding technique lies in its inherent ability to make these special print outs possible with only a small amount of re-programming effort by Dahlgren. I believe that re-programming to accomplish this task without the aid of this type of coding would be prohibitive if not impossible. Many of our problems of communication in the Laboratory were solved by the innovation of 5th and 6th digit print outs. In the past it was necessary to review PERT networks with group leaders every week or two and to verbally reconstruct the chain of events, while constantly referring to and shuffling a fistful of print outs, a task both trying to the PERT coordinator and exasperating to the busy engineer. Today, all we have to do is hand the group leader his copy of the 6th digit print out. Quick reference to the first page avails him of the expected dates of events which he recognizes as his own, and he is now in the proper frame of mind to receive the PERT coordinator, to discuss the finer points of his network and to provide the necessary inputs for the computer. Along with his copy of the 6th digit print out, the group leader is supplied with copies of PERT network which include the path of his events. Our ability to transmit weekly inputs to the computer has been made possible in large part to the voluntary submission of data by group leaders, who, at their convenience, drop by our office or call us on the phone. We still get our exercise, however, running after a few die-hards who place a lot of faith in bar charts.

The 5th digit print out, which lists clearly and vividly the events peculiar to individual systems, has also proven to be very helpful to management, as it enables the analyzer to focus his attention on a single system while retaining a perspective of all systems. Each system has an ultimate destination or use, and, hence, the expected times for completion of sub-assemblies and final systems is of particular significance to various personnel both in and out of the Laboratory. We have further contributed to the value of these print outs and graphic reports by maintaining a highly selective method of assigning schedule data. We assign schedule dates only to events which we believe will be significant milestones in each system, and which we believe to be realistic target dates. These schedule dates become subject to change by the analysis which we perform, and, after due consideration of certain desirable target data and dates that PERT indicates are more realistic, we arrive at meaningful target dates towards which to work.

With reference to reducing the cycle of data transmission and receipt from ten days to two days, I will not belabor you with the details of this procedure except to say that we transmit our inputs directly to SP 12 and Dahlgren via TWX message. SP 12 receives their copy as a regular TWX message while Dahlgren receives the data on punched paper tape, a capability which is provided by a conventional attachment to any TWX machines. It is our understanding that Dahlgren then feeds the punched paper tape through a converter which automatically punches the information on IBM cards. By these two mechanical steps we have eliminated time lost when using the mails for data transmission and have also eliminated the need for manpower to type the data on IBM cards at Dahlgren. I really believe that Dahlgren is so pleased with the latter accomplishment that they are happy to process the input data that very same evening and are thus able to mail the resulting print outs the following morning. This is the type of service we have gained by streamlining our data transmission methods. I hope many of you here today will be able to adopt this proven method of data transmission.

As I mentioned before, a new and challenging area that we have recently entered is the coordination of sub-contractor planning, scheduling and support activity by establishing direct interfaces with the PERT networks of our major sub-contractors, Raytheon and General Electric. Representatives of these companies are here to provide the details of this relationship.

APPLICATION OF THE PERT TECHNIQUE TO THE INDUSTRIAL SUPPORT PROGRAM FOR THE POLARIS GUIDANCE SYSTEM ELECTRONICS

R. E. Froncello
Raytheon Missile Systems Division

I. Raytheon's participation in the POLARIS 123 Guidance System Program.

A. Industrial Support to MIT Instrumentation Laboratory.

1. Perform research and development directed towards the improvement of performance characteristics, greater reliability, and more economic production of components, sub-assemblies,

and assemblies of the Guidance System Electronics. This effort involves:

a. Circuit studies of MIT designs by Raytheon circuit and reliability engineers to determine the optimum configuration and most reliable components available for each circuit.

b. Studies of MIT packaging concept in order to arrive at a final package which is reliable and feasible to produce.

c. Development of test specifications and requirements for production testing of the final design.

d. Fabrication of developmental type hardware to prove out the design.

e. Documentation of Design for subsequent production.

B. Prototype Production.

1. Fabrication of the Block I Prototype 123 Guidance System Electronics for delivery to GEOD.

II. Application of the PERT system to plan tasks and report progress on the above efforts.

A. All Raytheon efforts covered by MIT Engineering Instructions (EI).

1. EI initiated by MIT or Raytheon but must be approved by MIT.

2. Using MIT PERT network, Raytheon and MIT determine EI's required for accomplishment of program. These are shown in appropriate position on network. (See Figure 11).

3. When EI is issued PERT group and responsible engineers formulate a detailed PERT chart for the effort (See Figure 12). Significant events from these charts are then inserted appropriately into the MIT charts. In this manner Raytheon inputs to the NORC computer are reported through the MIT networks for the Industrial Support Program. The information on these charts is updated through weekly meetings between Raytheon and MIT PERT personnel.

4. All events on the detailed EI charts are not reported to NORC but these are used internally by the responsible engineers to report progress on their efforts. They are updated weekly through informal discussions with the PERT group. Information gained at these discussions is then used in updating the MIT charts.

B. Block I Fabrication.

1. Plans for fabrication and delivery of Block I Systems are formulated by determining when certain required information will be available from the development program.

2. Since Raytheon will send inputs to the NORC Computer for the Block I System it was necessary to establish a PERT network independent of the MIT network. (See Figure 13). A base line of 7/1/50 was chosen. To determine the time required to complete the initial events on this chart, completion of predecessor events on the MIT chart with respect to the Base Line date were taken into account. For instance, referring to Figure 13, the activity between event 509-260 from the MIT network and event 721-001 requires an estimated 1, 2, 3 weeks. However, based on the MIT network, the expected time for completion of event 509-260 is 6 weeks after 7/1/60. Hence the estimate for completion of event 721-001 from base line is 7, 8, 9 weeks.

3. Estimates for commencement of the Block I Program will be revised whenever expected dates for predecessor events in the MIT network change as determined by NORC printouts.

4. The chart shown in Figure 13 covers the first Block I System. A similar chart will be prepared for each of the succeeding systems.

PERTING POLARIS DOCUMENTATION

W. E. Hodgkins
R. G. Hall
LMSD

I. INTRODUCTION

For the purpose of this presentation documentation may be defined as those contractual documents required by the customer for complete design disclosure of the missile and its supporting equipment. This is a progressive function starting with the design and following through manufacturing, testing and field operations. All of these documents are required at specific times during the program and must be prepared in accordance with predetermined Navy format.

A. STATEMENT OF THE PROBLEM. It is during the research and development phase that project management finds it difficult to define on paper the status of any given configuration for a particular missile model. This is due to the rapidity and volume of design changes that are bound to take place during the theoretical and bread-board phases of any design effort.

B. PRODUCT ANALYSIS SOLUTION. Product Analysis at LMSD has the responsibility to review the design disclosure for compatability of one specification to another and to assure that these documents conform to the basic specification structure. This function requires the physical sign-off of each of the documents as certification to the customer that the task has been performed and the design, as submitted, represents Lockheed Missile Systems' best effort.

The task having been defined, we elected to use a set of ground rules closely approximating the actual contractual requirements. The methods, having been previously established in the PERT philosophy, completed the package by giving us the three basic essentials required for defining the job:

(1) Specific task definition

(2) Ground rules acceptable to the customer and compatible with established LMSD procedures

(3) Method of operation defined by LMSD PERT Task Force

II. NETWORK DEVELOPMENT

Our network was in effect an after-the-fact development, for having previously defined the task and having expressed it in positive contractual language, we had only to draw connecting lines between these items to establish key events. Interrelationships were then plotted as events that could be defined in the LMSD Management Procedures supported by Navy approved Drafting Practices. The third and last step, left only those events that can be described as constraints placed upon us by other outside functions, activities, or departments.

It is immediately obvious that all we have really done is to pictorially express the contract and integrate points in time with the existing procedures and practices already defined by Management Directives.

III. LMSD DESIGN CONTROL SYSTEM

In order to understand the problems peculiar to LMSD, it should be stated that the entire missile design is divided into thirty-nine (39) JRA (Job Release Assignment) Packages, each of which is assigned a two digit number. For example, Job Package # *50* encompasses the entire Second Stage Hydraulic System, inclusive of all supporting specifications and procedures. This Job Number carries over to the Manufacturing area and identifies the related Manufacturing segment as it appears on the Production Line Flow Chart. Being the only common denominator between design and Manufacturing, we elected to PERT the documentation on this basis which would enable the standardization of networks whose only variable would be the time between events. Thus the entire Design Documentation could be PERTed on one standard network using the two JRA Numbers to identify any sub-system of the missile.

A. WHEAT FROM THE CHAFF. A close examination of figure 14 (the Documentation Review Network) points out that all ending events are in fact contractual milestones in the order required by the customer. For instance, events 40 through 47, Acceptance Test Procedures, cannot be started until the Ordnance Specifications (OS) have been completed. This is defined by Navy specification and is therefore a matter of fact, and could not be plotted in any other sequence.

The experience gained during the generation of the first documentation PERT effort indicated that some sort of technique must be immediately devised to place factual data into the network if any degree of confidence in the final output and subsequent analyses was to be obtained. The classical technique of going to the source for information may be applicable to such fixed items as hardware, but when dealing with concepts and intangibles associated with documentation, such things as opinions, crimes of omission, and so-called engineering judgment left much to be desired. This then became the beginning of Phase II of our PERT evolution for documentation status.

IV. SEMI-AUTOMATION

This further refinement of the PERT technique encompasses the use of data being placed on IBM cards in place of previously maintained manual recording systems.

The need for keeping abreast of rapid design changes, which re-define the documentation review task and affect critical network time estimates, forced the Analysis & Control Section to create its own description, activities, and change control system.

This was accomplished by encoding on standard 80 column IBM cards all the information listed on Figure 15. By using the same pre-established encoding symbols for the PERT network, we could selectively run any portion of this data through a standard sorting machine and feed the information directly into any design network. Such information as number of drawings, process specifications, and Acceptance Test Procedures, valid for the design at the time the PERT report was prepared, could be determined accurately to the day when Analysis was due, thus assuring that the computer output was not obsolete five minutes after its release. Secondly, and of even greater value, was the confidence in the knowledge that we were dealing with facts and had eliminated the "best effort" sort of reporting previously experienced.

The fundamental difference is that now computer output is based on a one hundred per cent accurate input, or expressed another way, "facts-in equal facts out."

V. SUMMARY

The very nature of documentation, which is always in the fluid state during development, makes at the very best, the PERT Design Disclosure networks difficult to construct, maintain, and keep current. LMSD recognizes this fact, and is correcting the problem by maintaining on a daily basis the changes to all drawings, specifications, procedures parallel with contractual amendments and schedule revisions. Standardizing this information and maintaining it in a central control point makes possible the sum total or any portion applicable to PERT application available on demand. Thus the ability to define the job for any given point in time allows a realistic PERTing of design disclosure. This technique is referred to as "Positive Control-Projected Scheduling Project Impact" and the responsibility for each may be delegated to the applicable management areas. Napolean once said that one spy was worth a thousand troops. If you know what your enemy is going to do before he does it, you have 50% of the battle won. We in Analysis & Control subscribe to this theory and feel that the application of PERT to documentation status has given us the ability to accurately forecast slippage of those contractually required documents that may

appear on the critical path if a delinquency is allowed to occur. Automation of the design requirements adds to this the assurance that those contractually required documents have been accounted for. Experimental techniques to expand this application into such areas as Manpower loading and Financial operations are currently being pursued in joint operations with Lockheed Management Planning section, in order to give greater management control to our Project, our company, and the customer.

DAHLGREN 7090 COMPUTER OPERATIONS

R. N. LEARN
U. S. Naval Weapons Laboratory, Dahlgren, Va.

As you all know, we are presently processing the PERT data on the Naval Ordnance Research Calculator (NORC). In the latter part of September we plan to start processing the PERT data on an IBM 7090. Basically the processing procedures for both computers will be the same. However, on the IBM 7090 we are either planning or proposing to prepare additional reports. I want to talk about these "new" reports and other "new" developments in the processing of PERT data at the Naval Weapons Laboratory.

PERT SYSTEM INPUT

The "bulk" of the PERT system inputs come to NWL via the Special Projects Office (SP-12). I am referring to the forms titled "PERT-Report of Time Interval Estimates and Progress" prepared by the contractors. SP-12 reviews these forms to see if the input data for the computer is correct and also maintains (updates) the associated flow plans (networks). These review and maintenance functions are going to be assumed by NWL, Dahlgren. The contractors will then send the system inputs directly to Dahlgren, which we believe will have the effect of reducing the time required in the reporting cycle. It will also allow the personnel in SP-12 to concentrate on the analysis of the PERT outputs by subsystem and to analyze the effects on the entire FBM program. This shift of "review and maintenance" functions from SP-12 to NWL is one of the new developments in the PERT system input area.

Another fairly recent development in the PERT System Input area is the submission of inputs directly to NWL, using punched cards as the medium. This is being done by Lockheed, Aerojet, Hughes, and will be done in the near future by Sperry. With the exception of Hughes, these contractors have written computer programs for processing their own subsystems. They send the input cards to NWL for use by SP-12 in "simulation runs" and for "integrated runs."

The third new development in the input area is the use of commercial TWX as the input medium. MIT sends TWX messages directly to NWL. As the message is received, the data is automatically punched into five channel paper tape, thus eliminating the necessity of keypunching into cards the input data at NWL. This method of input transmission greatly reduces the time required in the reporting cycle because the input requires only minutes for transmission as opposed to the days required in the U. S. mails.

PERT SYSTEM OUTPUTS

In addition to the outputs we are presently preparing, we plan to prepare an activity oriented report (Figure 16). In this report two lines of data are shown for each activity. These data include all of the information shown in the event oriented report that we presently prepare, plus additional information concerning the activity. The Nomenclature, Earliest Expected Date, Latest Allowable Date, Schedule Date, Actual Date, Slack, Standard Deviation, Probability of Meeting Schedule, Short Path Flag, and Special Report Code are associated with the successor event of the activity shown. The A, M, and B are the optimistic, most likely, and pessimistic estimates of the activity. The Original—A, M, B, are the first time estimates submitted; the Current—A, M, B, are the latest time estimates submitted. The TE and VAR are the "expected time" and the "variance" computed for the activity using the Current—A, M, B. This activity oriented report, which is similar to those prepared at LMSD and AGC, enables the analyst to follow paths in the subsystem without the aid of the flow plan (network).

A proposed activity oriented graphic report is illustrated in Figure 17. This is effectively a graphic portrayal of a network in time sequence. The expected time for each of the activities in the network is represented by X's, E's, or L's which are entered on the three-year calendar in the period of time when the work is to be performed. The E's represent the period of time in which the activity would be performed if it were started as early as possible, i.e., on the Earliest Expected Date computed for the predecessor event. The L's represent the period of time in which the activity would be performed it it were started as late as possible, i.e., to be completed on the Earliest Expected Date computed for the successor event. When the E's and the L's overlap, X's are used to represent the activity time. Each X, E, and L represent two weeks of work.

Another proposed graphic report is Figure 18. This is an event oriented report. The X's represent that point in time when the event will be accomplished, based on the Earlist Expected Date computed for the event. The O represents that point in time when the end event is scheduled for accomplishment (schedule date). Figure 19 is a "Slack Analysis." It shows the number of weeks that events are ahead or behind schedule. Each X represents one week.

The last new development I would like to mention is the study we have just started at NWL. We

are going to make a computer analysis of the time estimates supplied by the contractors for PERT activities versus the "actual" time required for those activities. This study will allow us to evaluate the effectiveness of the approximation of expected time and to determine new weights or new methods if the results so indicate.

GENERAL SESSION

17 August 1960

Discussion of Working Group Recommendations

Chairman: CAPT. K. M. TEBO

Working Group Chairmen

Group I	R. S. Erickson, Control Data Corporation
Group II	D. H. Burnham, Westinghouse Electric Corporation
Group III	J. D. Blitch, LMSD

WORKING GROUP MEMBERS

GROUP I	GROUP II	GROUP III
Amico, G. V.	Archibald, R. D.	Blitch, J. D.
Bonquet, John	Burnham, D. H.	Bogdan, A.
Carter, R. P.	Froncello, R. E.	Cariski, S. A.
Dunipace, K.	Hansen, B. J.	Ciochetto, J. J.
Erickson, R. S.	Kester, W.	Henry, R. T.
Geri, Ltjg. Don	Lindquist, H. R.	Halzel, I.
Goff, D. S.	Patterson, W. B.	Leam, R. N.
Gould, R. D.	Savage, P. P.	Marshall, R. R.
Jenkins, C. W.	Sharpe, C. B.	Phelps, H. S.
Nupp, T. A.	Turner, C. S.	Rich, G. K.
Reuter, C. L.	Valiasek, J. W.	Sciara, Don
Ross, T. E.	Walsh, Tom	Smith, LCol., D. C.
Sager, R. D.	Williams, Ken	
Salzer, J. R.	Young, Richard M. T.	
Sliney, J. G.		
Soth, G. N.		
VanDolson, George		
Veccia, Ltjg. J. E.		
Williams, R. N.		

DISCUSSION OF WORKING GROUP RECOMMENDATIONS 17 August 1960

Conferees were divided into three working groups and provided with an agenda as a basis for discussion and recommendations for action to SP. The following are the summary minutes of the general meeting held as an afternoon session on 17 August 1960 to discuss the working group comments and recommendations as presented by the respective chairmen.

1. DECENTRALIZATION OF COMPUTER OPERATIONS ON A REGIONAL BASIS

Contractors comments.

Group I. It was recommended that the question of advisability of regional computer operations decentralization be reopened in view of success with TWX reporting to Dahlgren. It was further recommended that inputs be directly transmitted to Dahlgren by TWX. The group requested formats to be used. Exploration by SP for declassifying inputs and outputs to expedite communications was requested.

Group II. Half of the group are either using or are planning to use their own computers. Others use NORC now but are not opposed to computer decentralization if done at a disinterested computer facility.

Group III. Five companies are using or planning to use their own computers. Four companies are using outside computers. Reevaluate the study of the benefits of decentralization as a concept versus use of NORC with rapid communications.

Sp-12 Action. Captain Tebo stated that in view of rapid communications now being developed via TWX between Dahlgren and the contractors, as in the case of MIT and Hughes, the plan for decentralization of computer operations on a regional basis will be shelved. In order to further accelerate communications, plans are under way for submission of all PERT reports directly to Dahlgren rather than via Sp-12. Instructions on the timing of this transfer will be issued to all contractors in the early part of September. All contractors planning to use TWX communications were requested to give their names to Bob Learn of NWL. NWL will send instructions to contractors on the TWX format to be used for PERT inputs by the first week of September. Those submitting PERT inputs via TWX will receive negative slack readout TWX from Dahlgren followed by regular computer outputs via airmail special delivery. Those contractors not using TWX for inputs will receive the regular computer outputs by airmail special delivery. Declassification of PERT inputs and outputs will be fully explored in SP and contractors will be notified individually on their own reports.

2. PUBLICATION OF PERT MONTHLY NEWSLETTER BY SP-12

Contractors comments. Sp-12 should put out a monthly newsletter to include such items as computer operations by various contractors and governmental agencies.

Sp-12 Action. First newsletter will be published by 1 October 1960 provided at least five contractors submit articles to be included.

3. SUBMISSION TO SP OF CONTRACTOR PERT ANALYSES

Contractors comments.

Group I. Consensus of group is that PERT analysis should be provided by the contractors.

Group II. Many of the contractors are now doing this, as in the case of LMSD and Aerojet. If SP desires this, other contractor management should be requested to do likewise. Attempt should be made to consolidate with other existing reports.

Group III. SP should make contractor analysis a requirement of the system. SP should put out general requirements for reporting in the PERT system with whatever assurance possible of a reduction of other systems of reporting as PERT becomes more effective. This should take the form of consolidation of existing SP instructions into one current over-all directive. SP should set up a Reports Control Board for review and control of all existing program progress reports required by SP and without whose approval no new reports of a recurring nature can be instituted.

Sp-12 Action. Contractor PERT analysis will be made a part of the PERT reporting system. Directives on program progress reports will be updated and consolidated. Problem of duplicatory progress reports is fully recognized and every effort is being made in SP to minimize reporting requirements on contractors consistent with SP needs. It must be recognized, however, that the nature, extent of detail and frequency of the reports will vary according to specific level of requirements within SP. It is important to maintain the flexibility of the reporting system to meet the rapidly changing requirements of the FBM Weapons System program. SP will continue to review all progress reports on a regular basis to assure consolidation of reports wherever practicable and eliminate reports which have outlived their usefulness.

4. DEVELOPMENT OF INTEGRATED PERT NETWORK FOR INTER-PRIME CONTRACTOR COORDINATION

Contractors comments.

Group I. Contractors should coordinate their efforts in developing the integrated PERT network and define interface events and activities. SP should take action, if the problems are not resolved by the contractors.

Group II. Integrated network is very important. It is recommended that SP initiate getting interface events and activities. SP should take action, if the problems are not resolved by the contractors.

Group III. No comment. Covered sufficiently the day before.

Sp-12 Action. Coordination in the development and the maintenance of an integrated PERT network at the component level will be assigned to the prime contractor, as in the case of the missile system to LMSD. SP will provide the guidance necessary for coordination of prime contractors' efforts for the development and the maintenance of the integrated networks.

5. USE OF PERT BY PRIME CONTRACTOR FOR SUBCONTRACTOR PROGRAM COORDINATION

Contractors comments.

Group I. Depending on the size and contractor knowledge of subcontractor, subcontractor can be asked to supply a complete network or time estimates for interface events on the prime contractor chart and should be made to report thereon.

Group II. Use of PERT is recommended for major vendors on critical items only and should be made a part of contractual obligations.

Group III. No comment. The subject was believed to be sufficiently covered in the MIT presentation and in the discussion which followed on the first day of the meeting.

Sp-12 Comment. In the development of prime contractor PERT network, subcontractors assigned major or critical developmental projects should be PERTed to tie in with the over all network when problems are expected which will affect the scheduled date for the component shipment. Otherwise, the prime contractor is responsible to determine what formal method (milestone, LOB, PERT) should be used for reports by the subcontractors.

6. USE OF PERT FOR FBM WEAPONS SYSTEM PRODUCTION VERSUS RESEARCH AND DEVELOPMENT ACTIVITIES

Contractors comments.

Group I. It was the expressed opinion of the group that PERT is equally applicable in production and in research. For manufacturing, it might only be used as a planning tool because other methods of reporting progress may be more economical.

Group II. At this stage of PERT evolution and with manpower available, efforts would be better pointed toward R&D. Several contractors are exploring this field. Definition of production is controversial.

Group III. No Comment. Individual company should determine.

Sp-12 Comment. Use of PERT for production should be explored by individual companies, especially when full production experience has not yet been attained. Aerojet-General is taking the lead on this for the A1P motors.

7. CONTRACTOR PERT ORGANIZATIONS

Contractors comments.

Group I. Most PERT operating groups are a staff organization. They report to a line organization man responsible for the program.

Group II. It is recommended that each company send to Sp-12 some kind of organization chart of its operations for inclusion in the minutes. This should show relation of PERT personnel to the rest of the company of plant.

Group III. Because of the differences in organizational structures in the various companies, this was discussed only briefly.

Sp-12 Comments. This subject was included as a matter of mutual contractor interest. In view of the differences of opinion expressed on the value of publishing contractor PERT organizational structure, contractors wishing to submit organization data to Sp 12 should do so and we will consolidate and circulate to those interested.

8. ADVANCED COMPUTER PROGRAMMING TECHNIQUES FOR IMPROVING PERT COMMUNICATIONS

Contractors comments.

Group I. Half of the group recommended printing completion date on report as long as the completed events remain on the output sheets. Interest was expressed in the computer graphic presentation method shown by Bob Learn the day before.

Group II. Group liked the graphic computer outputs. Preferred Figure 19 format. The group would like critical path, some subcritical paths, and also potential for other special paths which would be coded accordingly. Liked Figure 18 also. Would like to keep Figure 17 capability.

Group III. Maintain information printed out in basic forms until everyone has had sufficient experience to warrant extension into more sophisticated types of printouts. NORC and Sp 12 continue studies and experimentation along this line for exploitation where appropriate. Contractors developing any different system keep Sp 12 informed so that Sp 12 can inform everyone by use of the newsletter.

Sp 12 Action. 7090 Computer at Dahlgren will be programmed for activity oriented outputs in addition to event oriented, as is now the case. This activity oriented output also will be provided to contractors if desired. The 7090 computer will be programmed to provide the graphic displays that were presented at the meeting. Companies interested in individual graphic reports will let NWL, Dahlgren know which reports they desire. Completion dates of events will be retained in the printout as long as completed events remain on the printouts.

9. CONTRACTOR EXPERIMENTATION WITH THE EXTENSION OF PERT TECHNIQUE AND PLANS FOR RESOURCE APPLICATION EVALUATION

Contractors comments.

Group I. Some contractors are studying or planning to make extension, but as yet have no results to report. It is recommended that PERT be applicable to proposals.

Group II. Much interest was expressed. Aerojet is now doing some studies. Suggest regular inclusion in minutes of new exploration and studies being pursued by contractors in FBM program so others interested can contact.

Group III. Much interest was expressed. PERT lends itself to extension and should be explored in every way.

Sp-12 Action. Request for proposal for PERTing cost will be signed off in SP during the week of 22 August 1960. (Ed. Note: Signed out 25 Aug. 1960). We are interested in the results of the experimentation being conducted by contractors in extending the PERT technique to continually improve the system for program evaluation in the FBM program.

10. NEXT PERT COORDINATION TASK GROUP MEETING

Contractors comments. These meetings are most worthwhile and should be held at least at six month intervals.

Sp-12 Action. Next meeting will be held in February 1961. Location will be later determined.

Overall Program Evaluation
(Integrated Network)

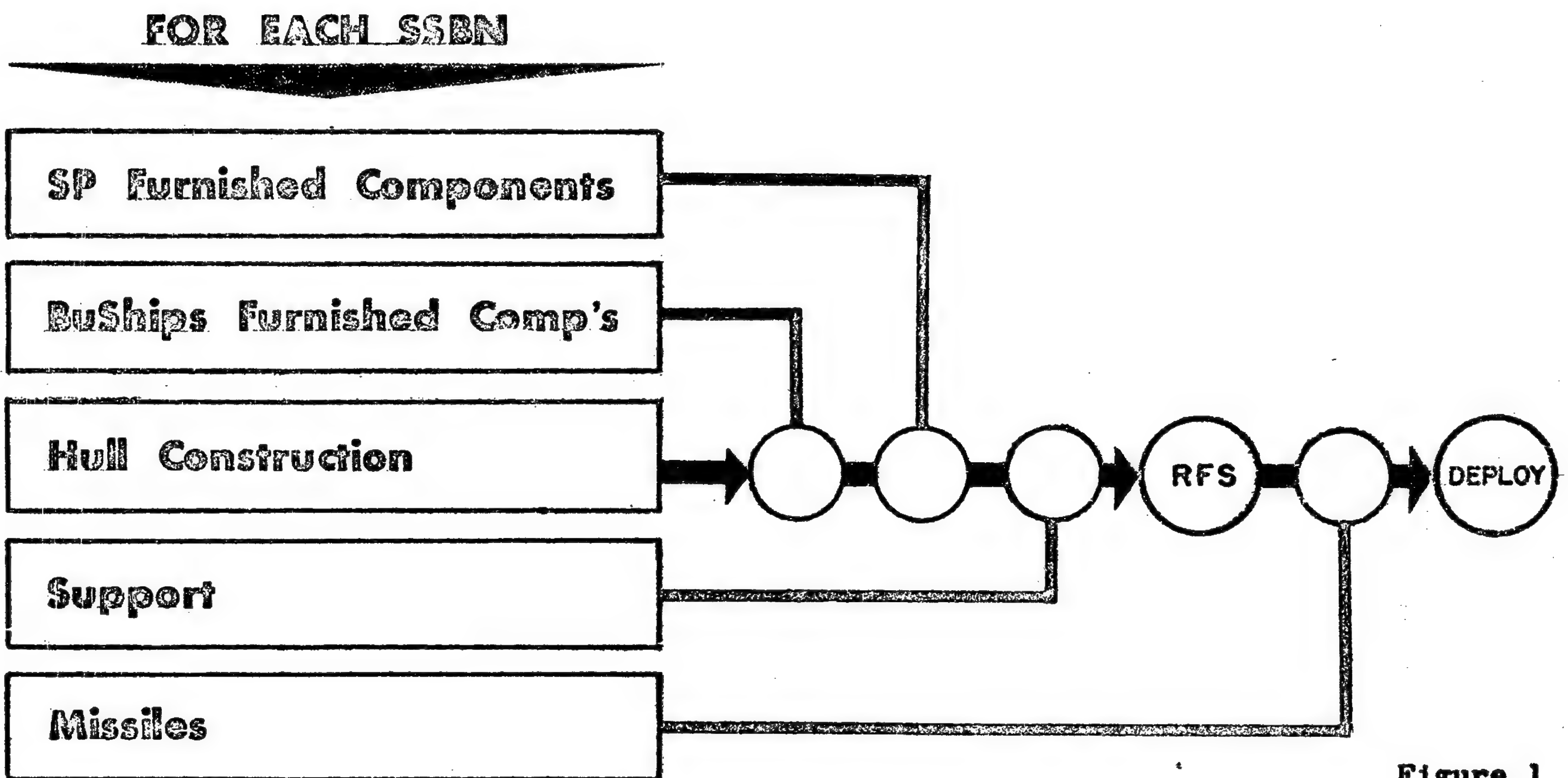


Figure 1

SPERRY GYROSCOPE CO.

MARINE DIVISION

PERT NAVIGATION SYSTEM ORGANIZATION

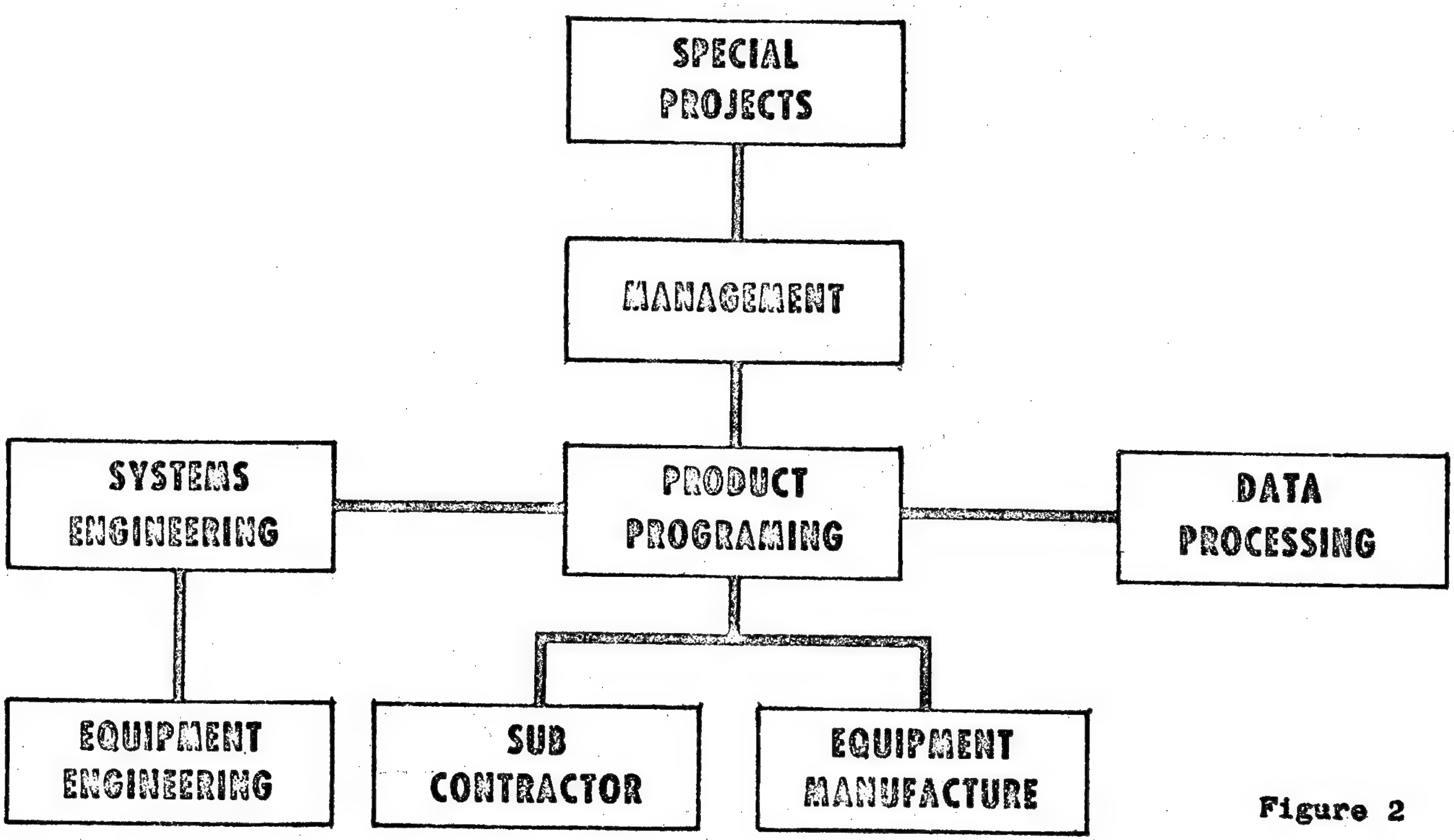


Figure 2

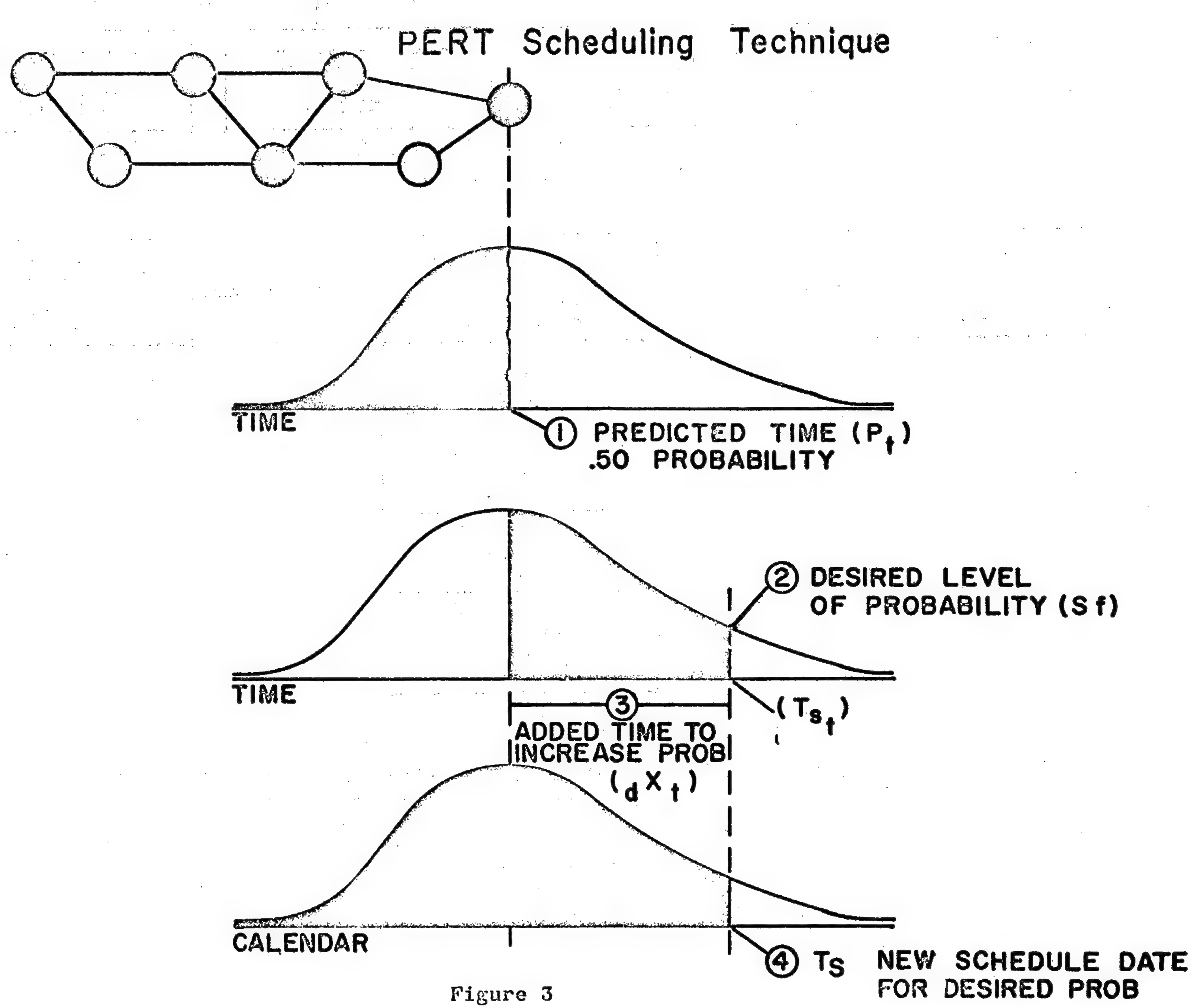

PERT Scheduling Technique
TIME
1 PREDICTED TIME (P_t)
.50 PROBABILITY
2 DESIRED LEVEL
OF PROBABILITY (S f)
TIME
(T_{s_t})
3
ADDED TIME TO
INCREASE PROB
($_dX_t$)
CALENDAR
4 Ts
NEW SCHEDULE DATE
FOR DESIRED PROB

Figure 3

Figure 4

AGC TEMP 1355

PERT - INPUT SHEET - MOTOR DATA

CONTROL CARD: C | RUN DESCRIPTION | ZERO DATE | LAST EVENT

PREC. EVENT NUMBER	SUCC. EVENT NUMBER	OPT. TIME EST.	MOST LIKELY TIME EST.	PESS. TIME EST.	COMPLETION DATE			SCHEDULE DATE			ORIGINAL SCHEDULE DATE			MISL	PROJ	MOTR	TYPE	OBJT.	FLT. OR TEST ASIGN NO.	AGC MOTOR NO.	STG.	ACTIVITY DESCRIPTION	PREC/SUCC OPERATION NUMBERS	CODE
					MO.	DAY	YR.	MO.	DAY	YR.	MO.	DAY	YR.											

AEROJET — GENERAL CORPORATION
ROCKET PLANT — SACRAMENTO, CALIF.

MISSILE ASSIGN. NUMBER	AGC MOTOR NO.	TYPE	STG	DELIVERY DATE PREDICTED	DELIVERY DATE SCHEDULE	PROBABILITY OF MEETING SCHEDULE	LAST PERT EVENT	DATE OF OCCURRENCE
P F 9		FLIGHT DELIVERY	1	01/17/61	01/20/61	.58		
P F 9		FLIGHT DELIVERY	2	01/31/61	01/20/61	.18		
P F 0		FLIGHT DELIVERY	1	01/17/61	01/23/61	.66		
P F 0		FLIGHT DELIVERY	2	02/07/61	01/23/61	.10		
P F 1		FLIGHT DELIVERY	1	01/24/61	01/25/61	.52		
P F 1		FLIGHT DELIVERY	2	02/07/61	01/25/61	.14		
P F 2		FLIGHT DELIVERY	1	01/24/61	01/26/61	.55		
P F 2		FLIGHT DELIVERY	2	02/07/61	01/26/61	.16		
P F 3		FLIGHT DELIVERY	1	01/24/61	01/30/61	.66		
P F 3		FLIGHT DELIVERY	2	02/07/61	01/30/61	.25		
P F 4		FLIGHT DELIVERY	1	01/31/61	02/01/61	.52		
P F 4		FLIGHT DELIVERY	2	02/14/61	02/01/61	.14		
P F 5		FLIGHT DELIVERY	1	02/07/61	02/02/61	.36		
P F 5		FLIGHT DELIVERY	2	02/14/61	02/02/61	.16		
P F 6		FLIGHT DELIVERY	1	02/07/61	02/06/61	.46		
P F 6		FLIGHT DELIVERY	2	02/14/61	02/06/61	.25		
P F 7		FLIGHT DELIVERY	1	02/14/61	02/08/61	.33		
P F 7		FLIGHT DELIVERY	2	02/21/61	02/08/61	.14		
P F 8		FLIGHT DELIVERY	1	02/14/61	02/09/61	.36		
P F 8		FLIGHT DELIVERY	2	02/21/61	02/09/61	.16		
P F 9		FLIGHT DELIVERY	1	02/21/61	02/13/61	.28		
P F 9		FLIGHT DELIVERY	2	02/21/61	02/13/61	.25		
P F 0		FLIGHT DELIVERY	1	02/21/61	02/15/61	.33		
P F 0		FLIGHT DELIVERY	2	02/28/61	02/15/61	.14		
P F 1		FLIGHT DELIVERY	1	02/21/61	02/16/61	.36		
P F 1		FLIGHT DELIVERY	2	02/28/61	02/16/61	.16		
P F 2		FLIGHT DELIVERY	1	02/28/61	02/20/61	.28		
P F 2		FLIGHT DELIVERY	2	03/07/61	02/20/61	.10		
P F 3		FLIGHT DELIVERY	1	02/28/61	02/22/61	.33		
P F 3		FLIGHT DELIVERY	2	03/07/61	02/22/61	.14		
P F 4		FLIGHT DELIVERY	1	02/28/61	02/23/61	.36		
P F 4		FLIGHT DELIVERY	2	03/07/61	02/23/61	.16		
P F 5		FLIGHT DELIVERY	1	03/07/61	02/27/61	.28		
P F 5		FLIGHT DELIVERY	2	03/14/61	02/27/61	.10		

Figure 5

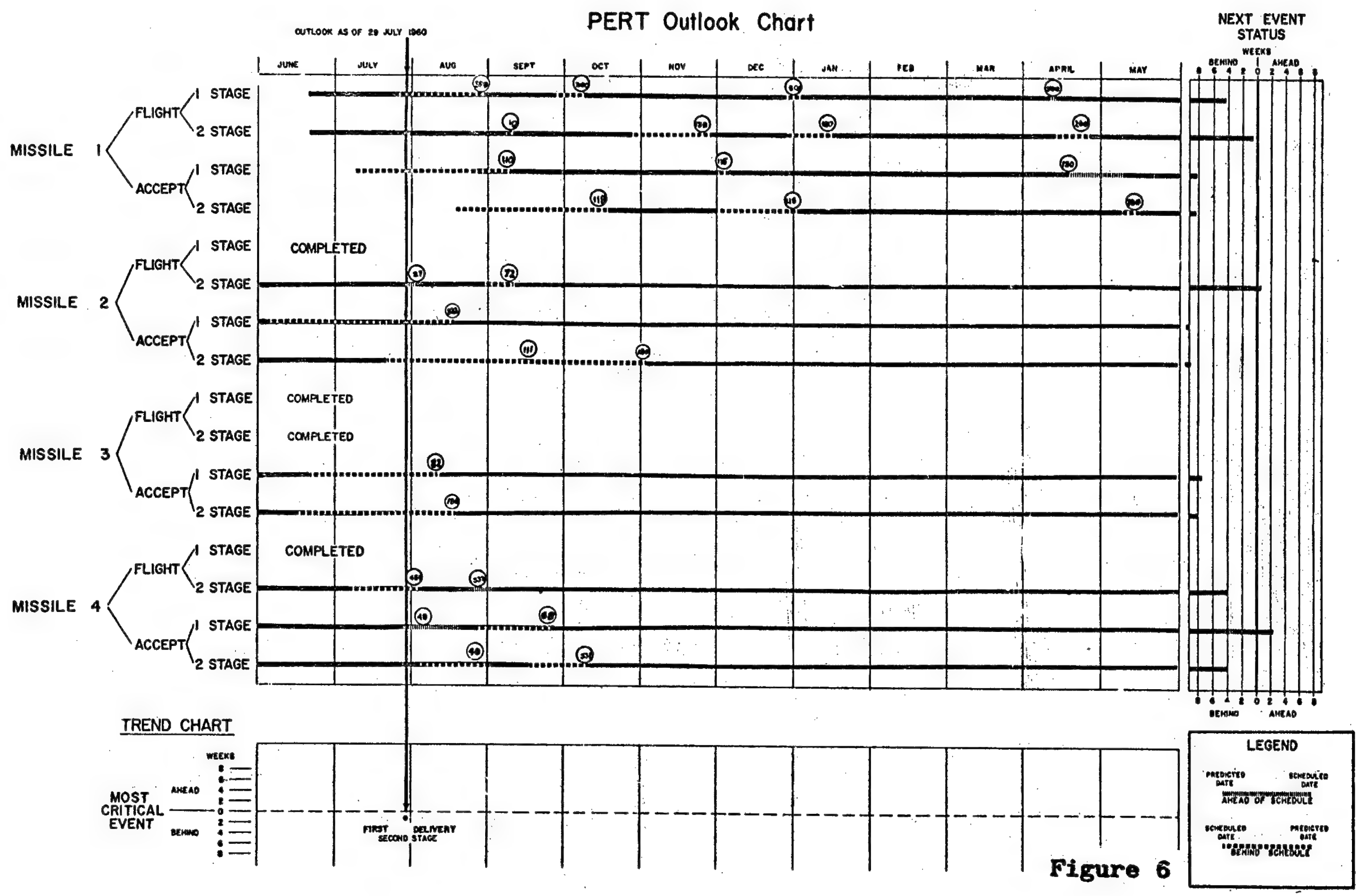
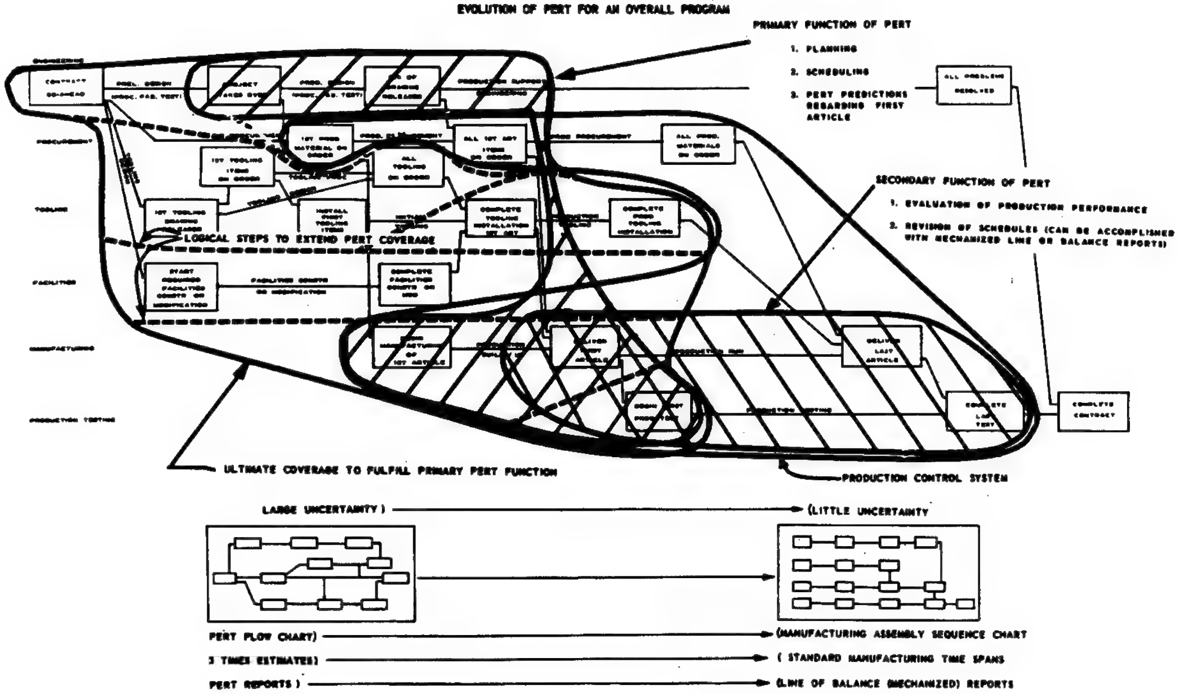

PERT Outlook Chart
OUTLOOK AS OF 29 JULY 1960
JUNE
JULY
AUG
SEPT
OCT
NOV
DEC
JAN
FEB
MAR
APRIL
MAY
NEXT EVENT STATUS
WEEKS
BEHIND
AHEAD
MISSILE 1
MISSILE 2
MISSILE 3
MISSILE 4
FLIGHT
ACCEPT
1 STAGE
2 STAGE
COMPLETED
TREND CHART
MOST CRITICAL EVENT
FIRST DELIVERY SECOND STAGE
LEGEND
PREDICTED DATE
SCHEDULED DATE
AHEAD OF SCHEDULE
BEHIND SCHEDULE

Figure 6

Figure 7

EVOLUTION OF PERT FOR AN OVERALL PROGRAM



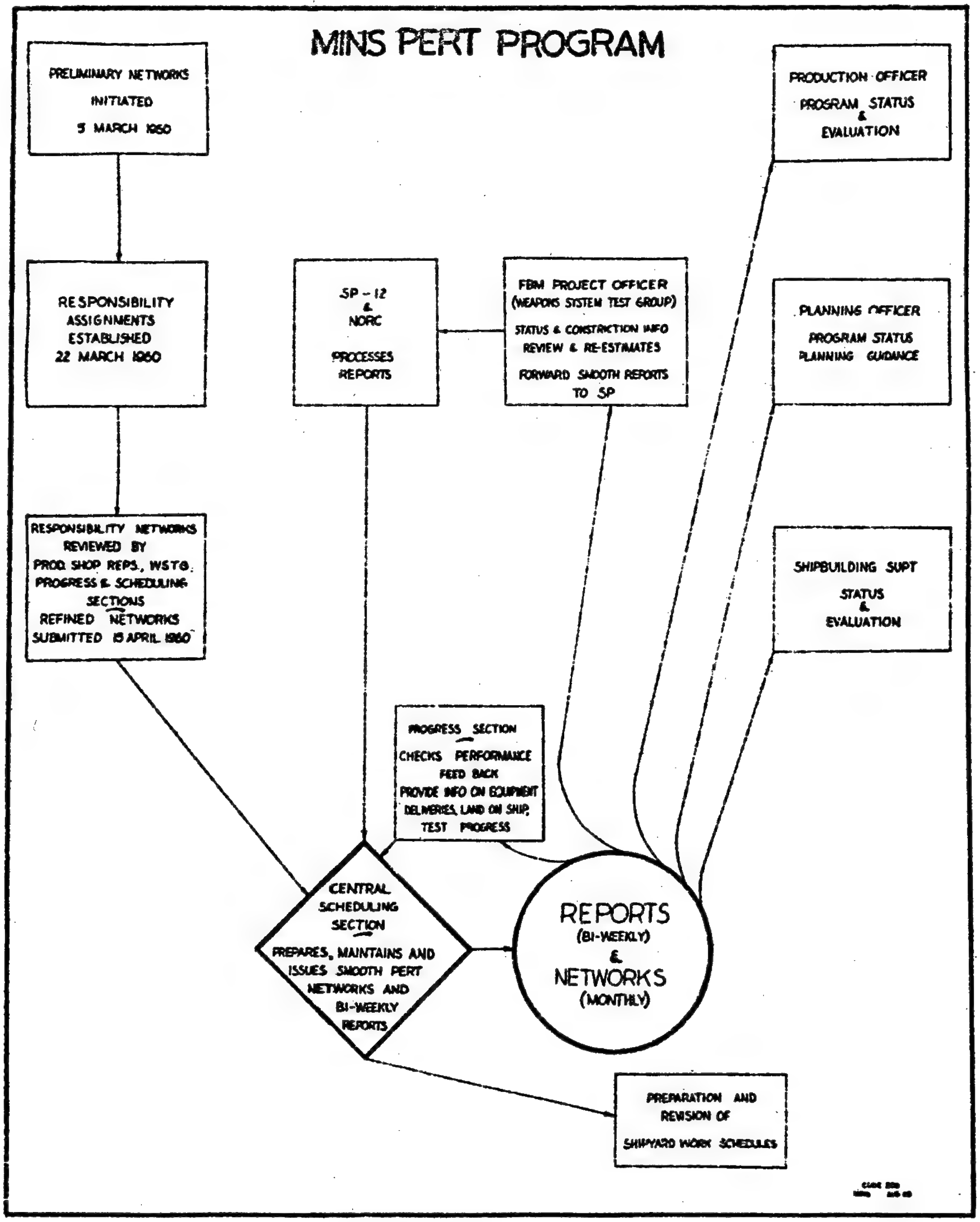

MINS PERT PROGRAM
PRELIMINARY NETWORKS INITIATED 5 MARCH 1960
RESPONSIBILITY ASSIGNMENTS ESTABLISHED 22 MARCH 1960
RESPONSIBILITY NETWORKS REVIEWED BY PROD. SHOP REPS., WSTG, PROGRESS & SCHEDULING SECTIONS
REFINED NETWORKS SUBMITTED 15 APRIL 1960
SP - 12 & NORC
PROCESSES REPORTS
FBM PROJECT OFFICER (WEAPONS SYSTEM TEST GROUP)
STATUS & CONSTRUCTION INFO
REVIEW & RE-ESTIMATES
FORWARD SMOOTH REPORTS TO SP
PRODUCTION OFFICER
PROGRAM STATUS & EVALUATION
PLANNING OFFICER
PROGRAM STATUS
PLANNING GUIDANCE
SHIPBUILDING SUPT
STATUS & EVALUATION
PROGRESS SECTION
CHECKS PERFORMANCE
FEED BACK
PROVIDE INFO ON EQUIPMENT DELIVERIES, LAND ON SHIP, TEST PROGRESS
CENTRAL SCHEDULING SECTION
PREPARES, MAINTAINS AND ISSUES SMOOTH PERT NETWORKS AND BI-WEEKLY REPORTS
REPORTS (BI-WEEKLY) & NETWORKS (MONTHLY)
PREPARATION AND REVISION OF SHIPYARD WORK SCHEDULES

Figure 8

MINS PERT NETWORK

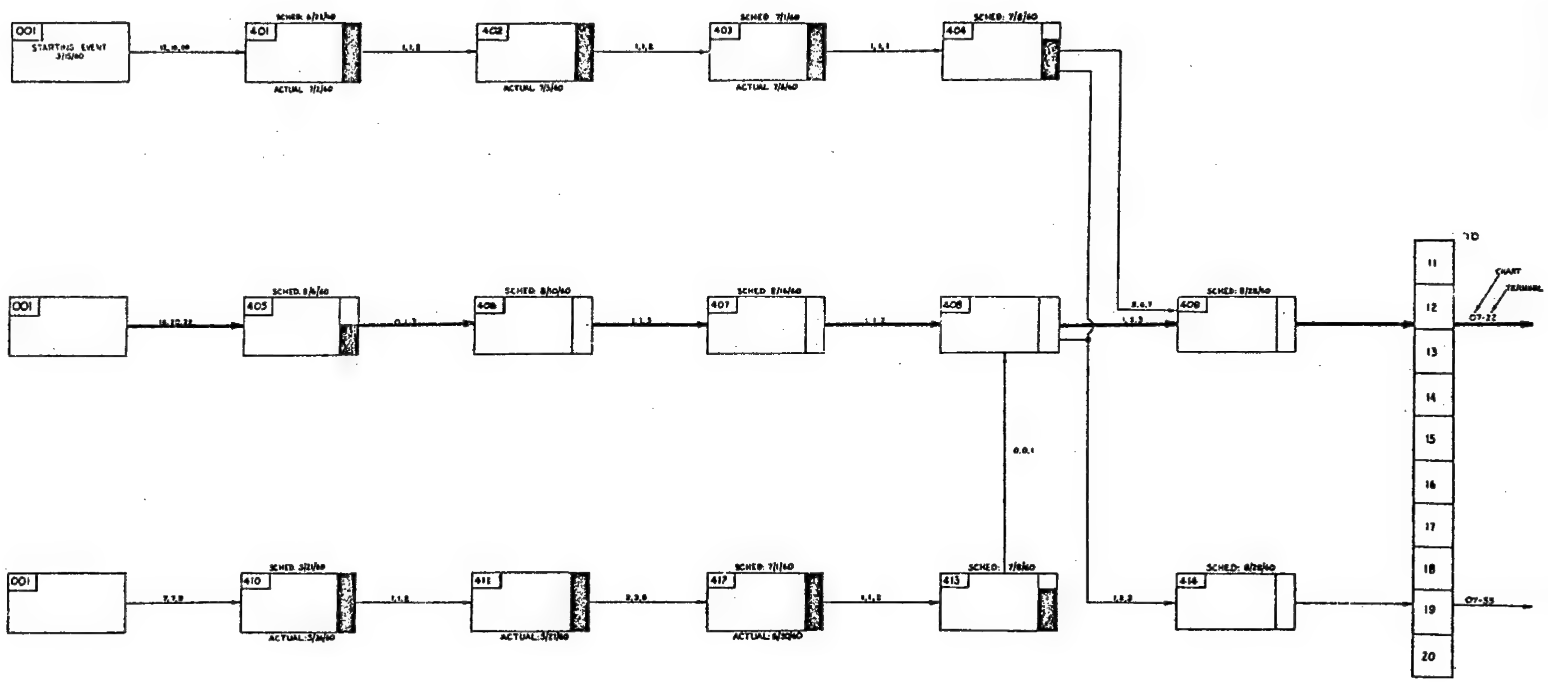


Figure 9

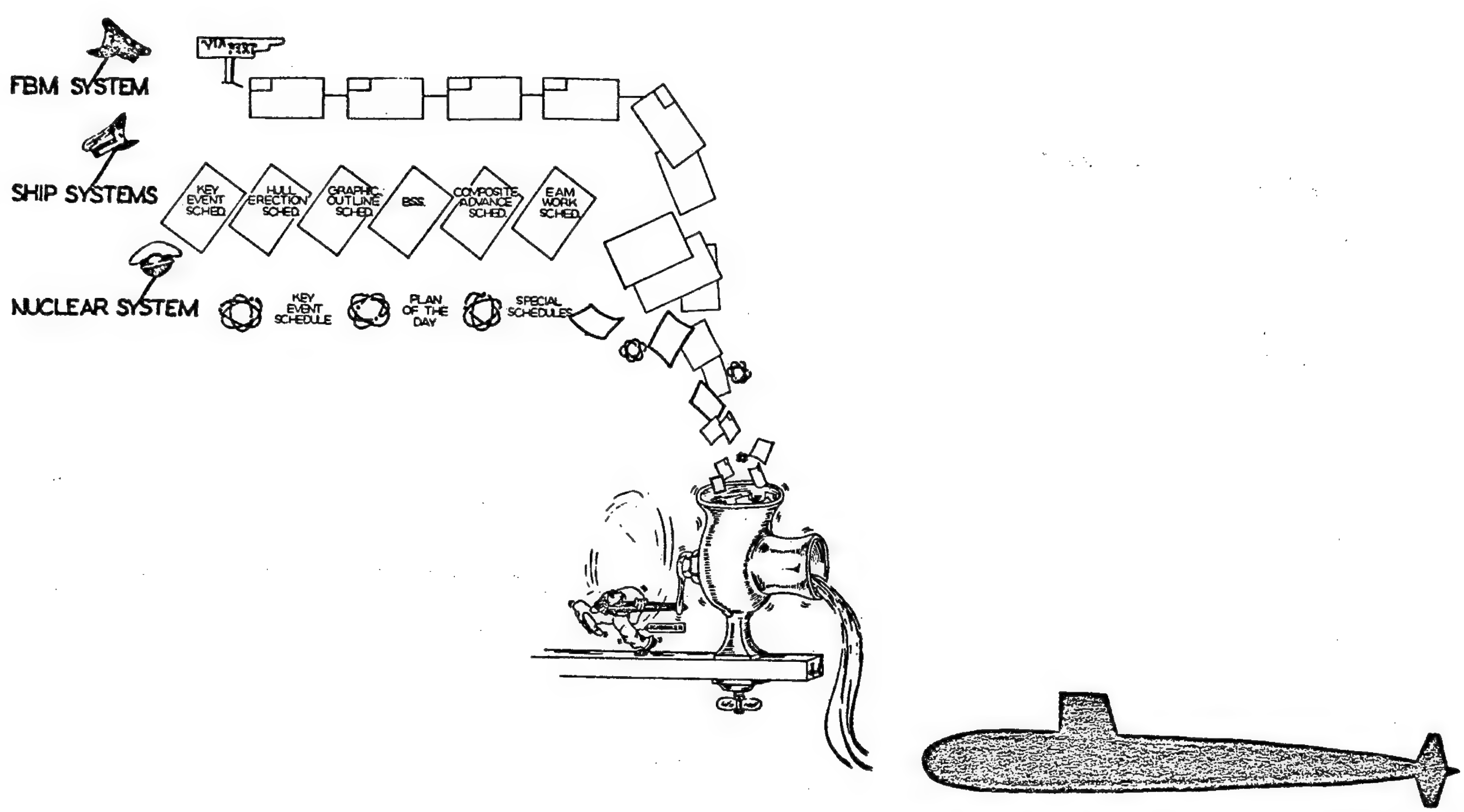
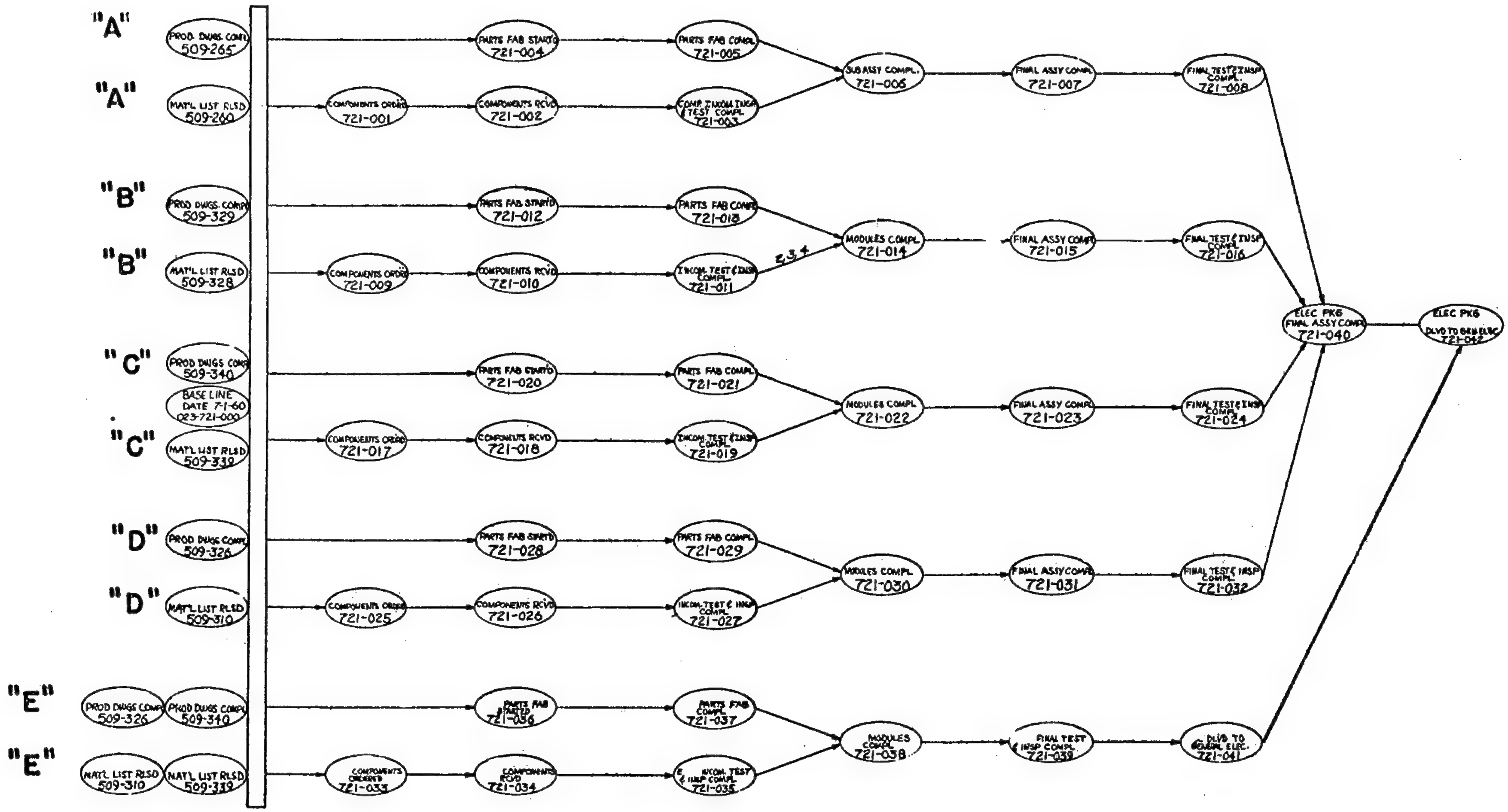


Figure 10

CODE 308
MINSY AUG.60

PAGES Fig 11 & 12
ARE
MISSING
IN
ORIGINAL
DOCUMENT



"A"
PROD. DWGS COMPL 509-265
"A"
MAT'L LIST RLSD 509-260
"B"
PROD DWGS COMPL 509-329
"B"
MAT'L LIST RLSD 509-328
"C"
PROD DWGS COMPL 509-340
BASE LINE DATE 7-1-60 023-721-000
"C"
MAT'L LIST RLSD 509-339
"D"
PROD DWGS COMPL 509-326
"D"
MAT'L LIST RLSD 509-310
"E"
PROD DWGS COMPL 509-326
PROD DWGS COMPL 509-340
"E"
MAT'L LIST RLSD 509-310
MAT'L LIST RLSD 509-339
PARTS FAB STARTD 721-004
COMPONENTS ORDRD 721-001
COMPONENTS RCVD 721-002
PARTS FAB COMPL 721-005
COMP INCOMING INSP & TEST COMPL 721-003
SUB ASSY COMPL 721-006
FINAL ASSY COMPL 721-007
FINAL TEST & INSP COMPL 721-008
PARTS FAB STARTD 721-012
COMPONENTS ORDRD 721-009
COMPONENTS RCVD 721-010
PARTS FAB COMPL 721-013
INCOM. TEST & INSP COMPL 721-011
2,3,4
MODULES COMPL 721-014
FINAL ASSY COMPL 721-015
FINAL TEST & INSP COMPL 721-016
PARTS FAB STARTD 721-020
COMPONENTS ORDRD 721-017
COMPONENTS RCVD 721-018
PARTS FAB COMPL 721-021
INCOM TEST & INSP COMPL 721-019
MODULES COMPL 721-022
FINAL ASSY COMPL 721-023
FINAL TEST & INSP COMPL 721-024
PARTS FAB STARTD 721-028
COMPONENTS ORDRD 721-025
COMPONENTS RCVD 721-026
PARTS FAB COMPL 721-029
INCOM TEST & INSP COMPL 721-027
MODULES COMPL 721-030
FINAL ASSY COMPL 721-031
FINAL TEST & INSP COMPL 721-032
PARTS FAB STARTED 721-036
COMPONENTS ORDERED 721-033
COMPONENTS RCVD 721-034
PARTS FAB COMPL 721-037
INCOM. TEST & INSP COMPL 721-035
MODULES COMPL 721-038
FINAL TEST & INSP COMPL 721-039
DLVD TO GENERAL ELEC. 721-041
ELEC PKG FINAL ASSY COMPL 721-040
ELEC PKG DLVD TO GEN ELEC 721-042

Figure 13

FIG 1*　PRODUCT ANALYSIS — DOCUMENTATION REVIEW

39 JRA PKG
20 NWA SEG.

LMSD OS	56
LMSD OD	374
LMSD PROC SPEC	127
AGC OS&OD	132

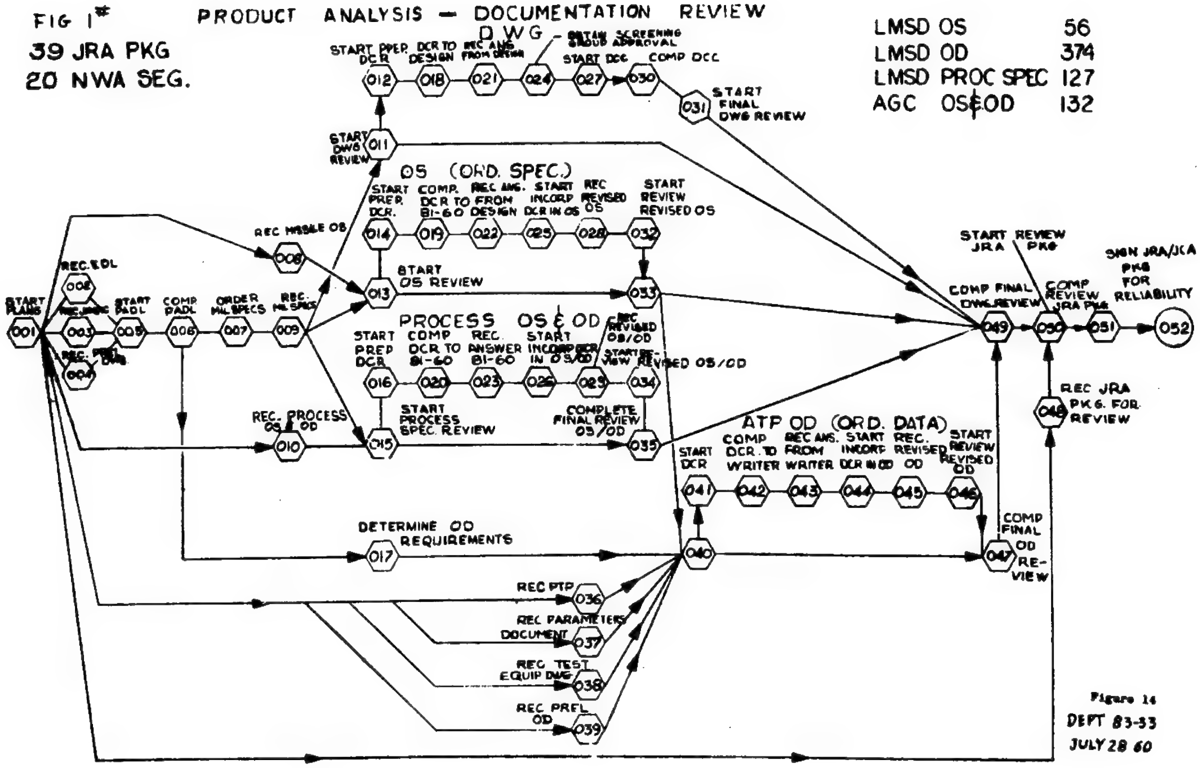


Figure 14
DEPT 83-33
JULY 28 60

ANALYSIS & CONTROL GROUP DEPT. 83-33

MISSILE INTELLIGENCE REPORT

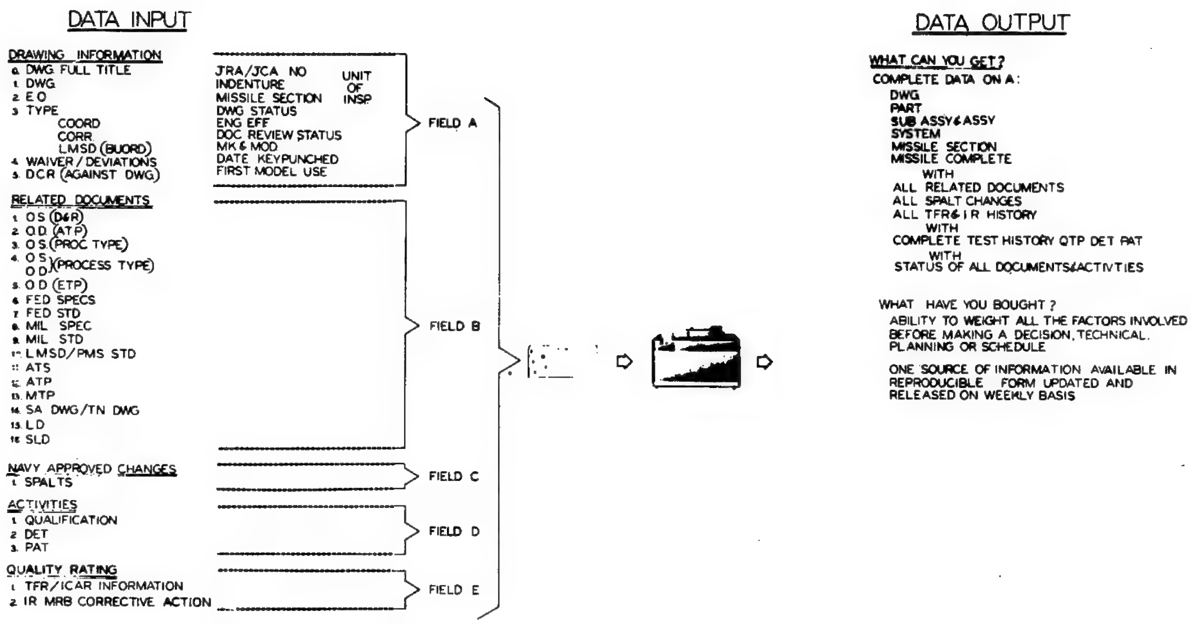


Figure 15

P E R T S Y S T E M

DATE 08/16/60 WEEK 77.7 SEQUENCE 10 PAGE 111 E

ACTIVITY PREDECESSOR	SUCCESSOR	NOMENCLATURE						EARLIEST EXPECTED DATE	LATEST ALLOW DATE	SCHEDULE DATE	ACTUAL DATE		SLACK
		ORIGINAL A	M	B	CURRENT A	M	B	TE	VAR	STD DEV	PROB	SHORT PATH FLAG	REPORT CODE
010000001	010000002	DESIGN DATA FEEDER FOR MSC						00/00/00	00/00/00	08/10/60	08/12/60		-1.8
		12.0	17.0	22.0	13.0	18.0	24.0	18.6	2.70	1.1	.48	0	0
010000002	010000003	CONSTRUCT MODEL FEEDER						09/10/60	09/01/60				-1.2
		3.0	5.0	7.0	3.0	5.0	7.0	5.0	.49	1.2		0	0
010000003	010000004	SELL MODEL						10/15/60	10/10/60	09/30/60			- .8
		18.0	22.0	30.0	20.0	30.0	40.0	30.0	2.89	2.0	.30	2	1
010000004	010000005	REDESIGN FEEDER						04/01/60	03/01/60				-4.0
		4.0	8.0	16.0	4.0	8.0	16.0	10.0	4.0	3.0		1	0

Figure 16

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                                PERT
                       GRAPHIC ACTIVITY REPORT

           DATE 7/26/60     WEEK 81.9     SEQUENCE 10     PAGE 1

PREDECESSOR    SUCCESSOR              1960                     1961                    1962
                             J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D

010 608 000    010 608 012                XXXXXXX
DELIVER SECOND DATICO
010 608 012    010 608 013                       XXXX
LAST HULL CLOSURE PLATE
010 608 013    010 608 015                          XX
SHIP LAUNCH
010 608 015    010 608 016                            x
LOAD CORE
010 608 016    010 608 017                             XXXX
INITIAL CRITICALITY
010 608 017    010 608 022                                 XXXXX
START SEA TRIALS
010 608 022    010 608 024                                      XXXXXXXX
COMPLETE PHASE 6 TESTS
010 608 024    010 608 028                                             X
SSBN 608 RFS
010 608 028    010 608 029                                              XXXXXXXX
SSBN ARRIVE NWA
010 608 029    010 608 038                                                     X
SSBN DEPLOYED
010 608 007    010 608 013                     EE  LL
DELIVER RADIOMETRIC SEXTANT
010 608 001    010 608 013                 EEEEXXLLLL
DEL FINAL LAUNCH TUBE ASSMBY
010 608 005    010 608 013                   EEEELLLL
DELIVER STAB DATA COMP
```

Figure 17

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                                                  PERT
                                        GRAPHIC ACTIVITY REPORT

                      DATE 7/26/60      WEEK 81.9      SEQUENCE 10     PAGE 1

                                       1960                      1961                      1962

                             J F M A M J  J A S O N D  J F M A M J  J A S O N D  J F M A M J  J A S O N D

DELIVER SECOND DATICO                            X

LAST HULL CLOSURE PLATE                              X

SHIP LAUNCH                                            X

LOAD CORE                                               X

INITIAL CRITICALITY                                         M

START SEA TRIALS                                                 X

COMPLETE PHASE VI TESTS                                                  X

SSBN 608 RFS                                                             X

SSBN ARRIVE NWA                                                                  X

SSBN DEPLOYED                                                                 0   X
```

Figure 18

PERT
GRAPHIC ACTIVITY REPORT

DATE 7/26/60 WEEK 81.9 SEQUENCE 10 PAGE 1

	WEEKS AHEAD OF SCHEDULE	WEEKS BEHIND SCHEDULE
DELIVER SECOND DATICO LAST HULL CLOSURE PLATE SHIP LAUNCH LOAD CORE INITIAL CRITICALITY START SEA TRIALS DELIVER LEVER CONTROL PANEL		.XXXXXXXX
DELIVER FIRST DATICO		.XXXXXX
DELIVER STAB DATA COMP		.X
COMPLETE DELIVERY NAVDAC I III	XX.	
LAST CREW MEMBER REPORTS BLUE	XXXX.	
FIRST MISSILE ARRIVE NWA	XXXXXXXX.	

Figure 19

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